WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Water Power and the O.E.E.C.

THE latest report on Intra-European Economic Co-operation in the Production and Distribution of Power* has been drawn up by Monsieur Louis Armand in his capacity as Consultant to the O.E.E.C. It is a compendious document of 114 typescript pages and deals with all aspects of energy generation and distribution, the new situation created by the advent of atomic energy and the future of traditional sources of energy.

With these broader problems we are not directly concerned, but we give here an outline of what Monsieur Armand has to say about hydro-electric power. He does not see any grounds for supposing that much further progress can be made with the mechanical part of hydro plant, and considers that economy in civil-engineering work could alone lead to lower capital outlay per kW capacity. In future, costing will no longer have to be based on "European coal price indices" if the aim is to achieve a genuine decrease in the price of energy, and in this matter it must not be forgotten that a plant programme forms a balanced whole in terms of the structure of demand and the general conditions of production.

On the other hand, a great diversity of site conditions exists in Europe. He regards their productive capacity as considerable but they are often situated far from the centres of consumption. This is particularly true of the potential sites in Northern and Western Scandinavia, Yugoslavia and Austria.

In 1950, he states, it was estimated that the profitable potential output from hydro plants in Norway, Yugoslavia and Austria amounted to 184,500 million kWh and as yet Norway and Austria had respectively exploited only 17 per cent. of their potential, and Yugoslavia only 2 per cent. By comparison, the total profitable potential of France, Great Britain and Switzerland amounted to 96,000 million kWh and Switzerland had already exploited 38 per cent. of her resources.

The capital costs of water-power schemes are still tending to rise in spite of modern methods of dam building, tunnelling and the higher voltages used for transmitting power, but in Norway most of the new schemes have wonderfully low costs—e.g., $133 per kW installed capacity as against an average of $268 for other member countries. To transmit energy from, say, northern Norway to the centres of industry in Europe is obviously out of the question with present-day techniques and if the best use is to be made of Norwegian resources it will be necessary to establish electro-metallurgical and electro-chemical industries near the sources of power supply.

Monsieur Armand considers that it might be possible for a broad measure of co-operation to be established between member countries by (a) first, making a general study of favourable hydro-electric sites, classified independently of national territories and solely on costs; and (b) second, to review the possible industries that might be set up near such sites. It is not impossible, he suggests, to imagine customs facilities established between member countries similar to those granted to free ports in respect of deliveries of raw materials and the despatch of finished products. Genuine concessions would then be granted in the "European industrial zones" thus constituted, to which countries where power is dear could transfer some of their works and factories.

Thus the O.E.E.C. might well consider the economic possibilities of such an arrangement for the benefit of the European economy as a whole. Other zones of the same type might be set up around the enormous sources of hydro power in certain African territories, which represent a considerable proportion of the world's potential of water power. In the French African territories, for instance, the Konkouré (Guinea) and the Kouilou (Middle Congo) schemes have a total production capacity of about 12,000 million kWh at a low cost.

Such sites can be compared with some of those recently opened up in Canada and are certainly not

* Published by the Information Division, Organisation for European Economic Co-operation, Chateau de la Muette, 2 Rue Andre Pascal, Paris 16.

less accessible, and their development might, within a very few years, bring Europe substantial additional supplies of cheap power which would enable certain industries to expand and become competitive on world markets. As in the case of natural gas, he concludes, cheap hydro power represents a hitherto unexploited source of energy which, if rapidly harnessed, could serve like an inhalation of oxygen to stimulate some sections of European industry.

World Power Conference, Vienna, 1956

THE Fifth World Power Conference will be held at Vienna next year, and the British National Committee have already made arrangements for two papers to be prepared under Section H which covers hydro-electric power developments. The first of these, by M. Braikevitch, A.C.G.I., D.I.C., Chief Hydraulic Engineer for The English Electric Co. Ltd., is to be presented under the title "Some British Developments in Large Plant for Hydro-Electric Power Generation," while the second, which will deal with "The Economics and Practical Application of Pumped Storage," will be a joint contribution by T. Lawrie, C.B.E., F.R.S.E., M.A., M.I.E.E., M.I.Mech.E., General Manager of the North of Scotland Hydro-Electric Board, T. G. N. Haldane, M.A. (Cantab.), M.I.C.E., M.I.E.E., of Messrs. Merz & McLellan, and R. W. Mountain, B.Sc. (Eng.), M.I.C.E., M.I.E.E., of Messrs. Kennedy and Donkin.

The Conference will extend from June 16 to June 23, 1956, and a series of post-Conference tour studies will begin on June 25, lasting from six to ten days according to the district visited.

Aluminium Limited's Expansion Programme

ACCORDING to the Annual Report published by Aluminium Limited a major expansion programme which has been in progress since 1951 was successfully completed in 1954 and the new facilities are all in production. These comprise the two new hydro-electric stations with total generating capacity of 540,000 h.p. and smelters of 71,500 tons capacity in the Province of Quebec, and the first stage of the Kemano-Kitimat project in the Province of British Columbia, with related alumina facilities in Jamaica.

At Kitimat the first potline in the new aluminium smelter went into production in August and the second in September. The rated capacity of these units is 91,500 tons of primary aluminium per year, or about one-sixth of the eventual planned capacity of 550,000 tons. For the past several months shipments of aluminium have been going forward to customers in North America and abroad, both by ship from Kitimat's own port and by the new rail line which now links the city with the transcontinental railway system. Although the pioneering atmosphere still prevails at Kitimat, good progress has been made in establishing the first 500 permanent homes and a self-governing municipality.

In October of 1954 the Company announced that the capacity of the Kitimat smelter would be immediately expanded to produce an additional 60,000 tons of aluminium ingot per year to meet the then estimated increase in the near-term demand for the Company's aluminium. This involves the installation of a fourth generator of 150,000 h.p. capacity in the Kemano powerhouse and the construction of additional potlines at Kitimat on which work is now proceeding. The expanded capacity is expected to come into operation early in 1956 at a capital cost of approximately $45 million.

Water Research in Hungary

HUNGARY'S new water research station on the Danube in Southern Budapest, claimed to be one of the largest in Central Europe, has now been completed. When fully established it will employ 45 research engineers and 80 scientific workers. The first task of the Institute will be the examination of flood embankments, of which there are 2,250 miles in Hungary, with a view to determining the most economical size and method of construction commensurate with safety.

Table Rock Contract

BALDWIN - LIMA - HAMILTON CORPORATION, Philadelphia, Pa., has been awarded a contract for approximately $750,000 to furnish penstock and spillway gates and gate hoists for the Table Rock Dam. Table Rock is a combination flood control and power generation project of the Corps of Engineers, U.S. Army, located on the White River 8 miles southwest of Branson, Mo.

Baldwin's contract, awarded by Morrison-Knudsen Company, Inc., Boise, Idaho, and Utah Construction Company, Salt Lake City, prime contractors, calls for four sliding-type penstock gates and ten Tainter-type spillway gates. They will be of all-welded steel fabrication. The penstock gates, 19 × 26 ft. and 2 ft. thick, will be furnished complete with roller-bearing trains and drum-type hoists. The spillway gates, 45 ft. wide and 40 ft. high, are designed to rotate on a 37 ft. radius. They will be equipped with reduction gear hoists. Shop erection will be made of the gates and hoists. Construction is to begin this year and delivery will start in 1956 to coincide with the construction progress schedule. Table Rock is scheduled to go into service in 1958.

Record Concrete Pouring at Roxburgh

A SINGLE pouring of 15,500 cu. yards of concrete at the Roxburgh hydro-electric scheme in the South Island was completed recently. The work, which took ten days, is thought to be a world record for a single pour, and pours of more than 2,000 cu. yards were made on two days.

European Cement Industry

THE O.E.E.C. Cement Working Party has published a survey of the European cement industry which reveal a more than average expansion throughout the industry in all O.E.E.C. countries. In the last few years there has been a steady rise in the production and consumption of cement which is in keeping with the trend in the last 30 years. Nevertheless, the annual rate of increased production, which was very rapid up to 1953, slowed down in 1954; however, there are still a number of large-scale projects for in-

creasing capacity, and there is some fear that in the more or less distant future production may outrun demand. Efforts must, therefore, be made to retain foreign markets and preserve the high level of domestic consumption which has mainly been kept up in the last few years by temporary demands such as those of hydro-electric equipment or the repair of war damage. In these circumstances, the O.E.E.C. Cement Working Party recommends the expansion of building programmes and the continued development of the growing tendency to seek new uses for cement.

Power Trend in New Zealand

THERE appears to be little likelihood of New Zealand embarking on an atomic power programme until her extensive water-power resources are very much more completely developed, especially in the North Island. This at any rate is the opinion of Mr. H. G. Nelson, deputy managing director of The English Electric Co. Ltd., who is at present on a business trip to New Zealand. In support of this opinion Mr. Nelson stated that although the capital outlay for a thermal plant was considerably less than that for an atomic plant the running costs, which involved the burning of coal or oil, were much higher; but neither could compete in economy with water power so long as so many suitable sites for hydro stations still remained undeveloped.

Progress in Ireland

ACCORDING to the Annual Report of the Electricity Supply Board of Ireland, the year ended March 31, 1955, was phenomenal from the standpoint of hydro-electric generation. The total units generated in the year by stations of all types was 1,458 million kWh, an increase of 12·8 per cent. over the previous year, and of this total, 779 million kWh, or 53·4 per cent., came from hydro stations, as against 590 million kWh in the previous year. This increase was due partly to the commissioning of the remaining 10 MW set at Cliff in December, 1954, but mainly to the exceptional rainfall, the average inflows on the Shannon and Erne having been almost the same as those in the previous two wettest years recorded since the completion of the Shannon scheme in 1929. These were the highest observed in the past 60 years with the exception of 1924/25. About £500,000 was saved on fuel during the past year as compared with a year of average water conditions.

In connection with the Erne development, about three-quarters of the work on dredging the channel between Belleek and Lower Lough Erne was carried out, and the construction of the new weir at Portora to regulate the Upper Lough was well advanced.

The river Lee scheme, consisting of a 19 MW station at Inniscarra and an 8 MW station at Carrigadrohid, is well advanced. At Inniscarra the diversion channel and part of the dam were completed and the river diverted early in the year, and concreting of the power station was in progress. At Carrigadrohid four blocks of the dam had been completed to full height, the stilling basin constructed, the river diverted, and important progress made on excavation work.

Excavation work was also well advanced on the Clady development in County Donegal. Both the Lee and the Clady schemes are scheduled for completion about 1957.

Investigations and hydrometric surveys were continued on 17 undeveloped rivers in the Irish Republic, and wind-power investigations have been in progress since 1950.

Lebanon Power and Water Supply

THE Lebanese Chamber of Deputies has approved a law establishing the National Litani Office as an autonomous governmental agency charged with the responsibility of drawing up annual construction programmes for the development of the Litani River waters with respect to electrification, irrigation, drainage and domestic water supply. Development of the Litani River basin will be based on a report presented to the Lebanon Government by U.S. Foreign Operations Mission in the Lebanon, which provides for a co-ordinated development programme over 25 years costing the equivalent of 100 million U.S. dollars. When completed it is estimated that 626 million kWh will be produced yearly. This scheme is considered essential for the country's development and a parliamentary investigatory committee has recommended that a large share of the country's finances should be used to implement it in the shortest possible time.

Austrian Power Loan

THE expansion and completion of various Austrian power plants will be aided by proceeds from the sale of Hydro-electric Power Loan bonds. In particular, this bond issue is to provide funds for the upper stage of Kaprun, the Moser and Drossen dams, for the Tauern power plant Schwarzach, due to be completed in 1958 with a maximum output of 120 MW, and an annual output of 400 million kWh.

Norwegian Underground Plants

IN four years' time one-third of the hydro-electric power stations in Norway will be underground installations, according to a White Paper recently published. It is also stated in the report that the amount of new hydro-electric capacity ready this year will be 586,700 kW. This will enable total annual hydro-electric output in Norway to rise to about 24,000 million kWh. By 1958 output should be about 28,000 million kWh.

Eau Bleu Project

IN Mauritius, work has begun on the new hydro-electric power project at Eau Bleu. Located in the midland region on the island, where the average yearly rainfall is about 160 in., the new station will include a dam, impounding some 5,000 acre ft. of water, which will be 800 yards long and have a maximum height of 63 ft. The plant is expected to produce five million kWh yearly and the cost of the scheme is estimated to be £255,000. A supplementary plan, entailing the diversion of additional waters into the reservoir, which would increase the production of electricity to eight million kWh annually, may be undertaken later at a cost of £112,500. The new plant is expected to be in service by the end of 1957.

Book Reviews

Straight-Drop Spillway Stilling Basin. By Charles A. Donnelly and Fred W. Blaisdell, Hydraulic Engineers, U.S.D.A., A.R.S. Technical Paper No. 15, Series B, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, U.S.A. 35 pp. Price 75 cents.

This study, which was conducted by the Research Service of the United States Department of Agriculture, describes the work undertaken to arrive at generalised design rules for a stilling basin with a straight-drop spillway—virtually a straight overfall weir. Experiments have shown the new design which has been evolved to be perfectly adequate in protecting the downstream channel from scour. Its simplicity suggests that it will be relatively cheap to construct, the water discharged over the crest falling on to a flat apron on which the nappe is broken up by a row of projecting floor blocks. It is claimed that the design can be satisfactorily used for a wide range of discharge rates, crest heads, crest lengths, total drops, and downstream tailwater levels. An important finding is that the stilling basin length computed for the minimum tailwater level to give a good performance may not be adequate for higher tailwater levels. In these latter conditions, dangerous scour may occur if the nappe is sufficiently supported by the high tailwater to land beyond the end of the stilling basin. In consequence, a method of computing the length for all tailwater levels is presented. An example shows how the rules are applied to the design of structures in the field.

Developed and Potential Water Power of the United States and Other Countries of the World. December, 1954. By Loyd L. Young. United States Department of the Interior, Geological Survey Circular 367. Free on application to the Geological Survey, Washington 25, D.C.

This circular gives in very concise form a most useful summary of developed and potential water-power resources throughout the world. The compilation of figures of this kind is notoriously difficult because of the incompleteness of available data, the differences in bases of estimation, and the pace of development, so that behind the four tables contained in this circular is a remarkable feat of correlation. In preparing the original estimates of the developed and potential water power of the world the estimates published by the various countries were used wherever available, but where studies of potential power had not been made the probable potential was determined from existing data on rainfall and topography. In cases where these data were later supplanted by estimates prepared in the countries concerned the two are said to have been in reasonable agreement.

According to Table I the total installed capacity of water-power plants throughout the world at the end of 1954 was 129,718,000 h.p., representing an increase of 564 per cent. on the position in 1920. In the United States the corresponding figures are 34,700,000 h.p.—26·8 per cent. of the world total—representing an increase over 1920 of 463 per cent.

In Table II is given a summary, by continents and by countries, of installed and potential water power. Accompanying the figure of installed water power in each case is the plant factor—the ratio of the average load to the aggregate installed capacity. Two sets of potential water-power figures are given, the first based on ordinary minimum flow, that is, flow available for 95 per cent. of the time with existing regulation, and the second based on mean average annual flow. On the basis of minimum flow the world potential is given as 648,620,000 h.p. and that of the United States 36,500,000 h.p. These figures, of course, take no account of future regulating works that will undoubtedly be installed. On the mean-flow basis the world potential is 3,078,950,000 h.p. and the United States potential 116,000,000 h.p. All these figures are based on 100 per cent. efficiency, and include all potential that it is physically possible to develop, irrespective of economic feasibility.

Table III is a detailed analysis of potential water power in the United States, based on 95 per cent. and 50 per cent. availability and on mean flow, assuming existing flow, 100 per cent. efficiency and gross head.

In Table IV similar figures are given based on existing storage and assumed development of known storage sites.

The circular concludes with a discussion of many points of interest revealed by the figures.

Water Over the Dam. This is the title of a 24 pp. booklet published by the Allis-Chalmers Manufacturing Company which traces the development of water power in America from the 17th century to the emergence of hydro power as the driving force for the production of electrical energy. In this development America has assumed a leading position, having the credit of inventing the Francis turbine and the Pelton wheel.

The records of water-power development in America go surprisingly far back and reference is made to a grist mill erected at Port Royal, Nova Scotia, which was first settled by emigrants from Scotland in 1605. Some of the later wheels are illustrated by photographs, notably one in the Clinch river valley near Knoxville which was built in 1798. The illustrations of some of the earlier turbines and Pelton wheels are also full of interest, and Mr. Edward Ushling, the author, has made an excellent job of the text. Copies of the booklet (02R8232) are available on request to the Allis-Chalmers Manufacturing Company, S 70th Street, Milwaukee, Wisconsin, U.S.A.

Water Supply Engineering. By Harold E. Babbitt and James J. Doland, respectively, Professors of Sanitary Engineering and Civil Engineering, University of Illinois. Published by McGraw-Hill Publishing Co. Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4; 9¼ in. × 6 in. × 1⅛ in., 608 pp. (including index). Illus. Price 61s.

This comprehensive text book has now reached its fifth edition and this in itself is a tribute to the esteem in which it is held in water-engineering circles. To those to whom it may still be unfamiliar it may be said to give a concise and detailed survey of water-supply engineering in all its aspects and the present edition has not only been enlarged to include information on industrial supplies but has also been revised to incorporate data on the latest accepted practices in this field.

The conciseness of the text results in a certain empiricism in treatment but it is difficult to see how this could have been avoided in a book of such wide

scope, for it deals with financial and administrative problems, the bases for estimating probable consumption, the amount of run off that may be expected, the hydraulics of flow in open and closed channels, corrosion and maintenance problems, pumps and pumping stations, dams and reservoirs, distributing systems, and purification.

Among the improvements made in the present edition are that 227 new problems have been introduced and more than 200 new references added to an already comprehensive bibliography.

Wasserkraftwerke (Water-power Plants), by Dr. Ing. Heinrich Press, Professor at the Berlin-Charlottenburg Technical University. Published by Wilhelm Ernst & Son, Berlin-Wilmersdorf. Vol. III of **Stauanlagen und Wasserkraftwerke** (Dams and Water-Power Plants), 6½ in. by 9½ in., VIII—340 pp., 356 ff., 1954. Distributed in the United Kingdom by Lange, Maxwell & Springer, Ltd., Maxwell House, 242, Marylebone Road, London, N.W.1. Price, cloth-bound, 52s. 6d.

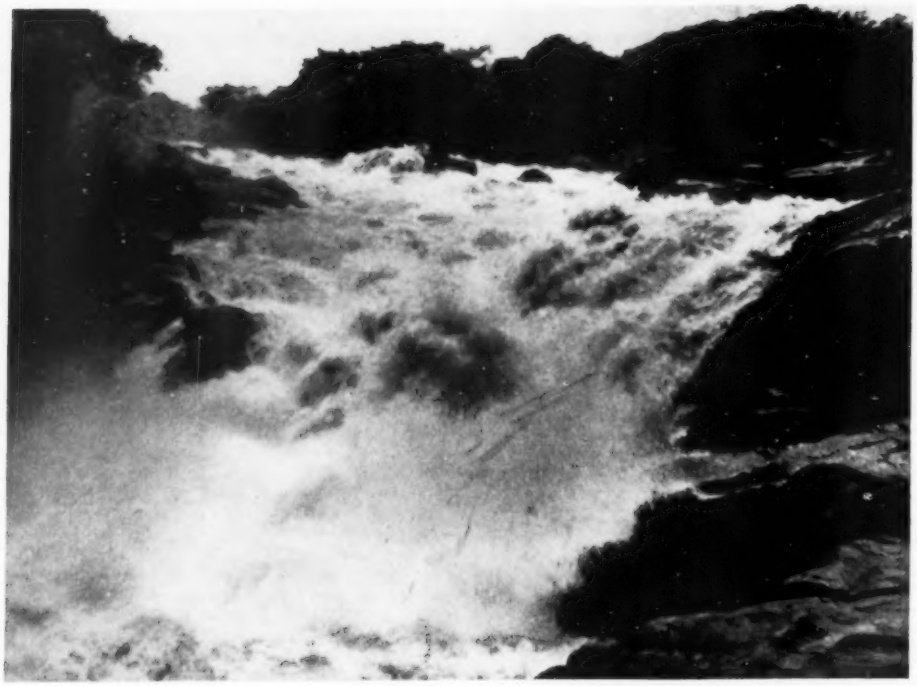
The symbols used in the work are defined in a short introduction, followed by a chapter of general considerations. The author then analyses the basic investigations on which hydro-electric projects are worked out, after which the various possibilities of remedying the natural fluctuation of power-water supply are examined in separate sub-sections. These discuss compensation by reservoir storage, diversions from other catchment areas, multi-stage development, co-ordinated release of power water in chains of run-of-river plants, control of consumption, co-ordination with other sources of energy, combined operation in grids, and pumped storage. Chapter 3 deals with the various types of installations in relation to the head of water available. Plants operated by a diversion canal, such as the Shannon and Donzère Mondragon, and pure run-of-river plants, are reviewed up to the most recent innovations. Pier-type plants in their various patterns and layouts—submerged or submersible plants, etc.—are also investigated. The conditions which guide the selection of a particular type or pattern of installation are discussed at length. High-head plants are divided into those types in which the power-house is integrated with the storage dam and variously supplied by pressure tunnels or shafts, penstocks, or, in exceptional instances, through gravity tunnels or canals. Surface and underground power plants are reviewed separately, the sub-section devoted to the latter filling no less than 23 pages. This chapter ends with a paragraph on tidal plants which, despite its brevity, contains all the fundamentals relating to this possible development. Short chapters on the economics of river development and on small plants conclude the first half of the volume. In the second half, intake works, power-conduits and power-houses proper, together with their respective equipment, are the subject of exhaustive chapters. All the various kinds of power conduits, from open channels to the latest types of penstocks (hooped, overpressured) are described, and discussed in all their aspects. The chapter on power-houses deals exclusively with the various types of turbines, their respective ranges of application being summarised in a table (p. 287) which gives their main characteristics (specific speed, head), in relation to the number of buckets in Pelton wheels and of the blades in Francis or Kaplan runners. Sub-sections deal with the fundamentals governing the design of high-head and low-head power-houses, as well as with operative and service features. The bibliography appended at the end of the book is virtually restricted to recent publications in German, and there is a very good index. This final instalment of Dr. Press's great work is in every respect up to the high standard set by the two first volumes (see WATER POWER, Dec., 1954, p. 448). Looking now upon the complete work, it would be difficult to discover any point connected with the civil and mechanical engineering aspects of hydro-electric development which has not been efficiently tackled, if not always at length at least in a summary and clear manner. The relative scarcity of mathematical calculations is thoroughly compensated by an abundance of judiciously selected examples of up-to-date developments, supported by excellent illustrations. Print, paper and binding leave nothing to be desired.

Foundation Engineering. By Rolt Hammond, A.C.G.I., A.M.I.C.E., with an Introduction by Sir F. Arthur Whitaker, K.C.B., M.Eng., M.I.C.E. Published by Odhams Press Limited, Long Acre, London, W.C.2; 9 in. × 6 in. × ⅝ in., 188 pp. Illus. 1955. Price 21s. net.

Although not directly related to hydro-electric engineering this book covers a wide range of practical foundation problems and thus has application to all kinds of foundation work. As Sir Arthur Whitaker states in his introduction, although mediaeval builders had some empirical knowledge of soil mechanics and were able to erect large buildings on subsoils, so making an advance on ancient builders who founded only on rock, the needs of modern industry are such that structures have now to be erected in situations which offer little choice in the selection of the foundations, with the result that the conditions encountered are legion and rarely does one problem match another at all points.

Mr. Hammond's book is concisely written and deals adequately with soil mechanics, site exploration, vibration-controlled foundations, foundations for houses, buildings, bridges, maritime structures and difficult foundation problems. The information is up-to-date and it is impossible to point to any other work in which it is so conveniently available to the busy engineer. An excellent bibliography is given at the end of each chapter and there is an adequate index.

Birtley Manufacturing Agreement. The Birtley Company Limited have entered into an agreement with Athey Products Corporation of Chicago, U.S.A., covering the manufacture of rubber-tyred and track-type wagons under licence from them and to their technical designs and specifications. These wagons will be manufactured under the name of "Birtley" and the arrangement is that The Birtley Company are free to sell these equipments throughout the world, through APCOR dealers, who will be responsible for servicing and parts provisioning. Production arrangements are now being made by The Birtley Company with a view to initial equipments being available early in 1956. The Birtley Company are in production already on the types 9A and 9S cable-operated bull-dozers, to match their D9 tractors, to the technical design and specification of Caterpillar Tractor Company.



The Shire Valley Project

Leading particulars are given of a vast scheme envisaged for the economic development of Nyasaland by controlling Lake Nyasa, reclaiming great areas of marsh, and erecting hydro-electric power stations*

THE Shire valley, which occupies the southern part of Nyasaland, marks the terminus of a major rift valley which traverses the African continent from the Red Sea to the Zambezi. The faulting system causing the rift has a throw which in places amounts to several thousand feet; in the Nyasaland section the lowered area, which forms a large part of the whole country, carries Lake Nyasa in the north and the Shire river, which drains the lake, in the south. On either flank of the valley the rocks consist mainly of crystalline gneisses and schists, while the floor is covered to a considerable depth with alluvial and sedimentary deposits. The flanking rocks are injected by syenitic intrusions which form much of the high ground around the south-eastern arm of the lake, the Zomba plateau and the Mlanje mountain. Altitudes vary enormously; most of the Mlanje block is over 5,000 ft. above sea level while the peak itself rises to 10,000 ft. and the high ground on both sides of the lake is all at an altitude of between 3,000 and 5,000 ft. On the other hand the lower portion of the Shire river, south of Chikwawa, is only about 150 ft. above sea level.

Lake Nyasa itself lies at an altitude of about 1,550 ft. and has a catchment area of 48,850 sq. miles, including the area of the lake. To this must be added a catchment of 12,260 sq. miles between Fort Johnston, near the head of the Shire, and the confluence with the Zambezi.

The highland areas are relatively cool, and grasslands are plentiful, the soil in many places being of good quality. Rainfall is abundant, especially north of the lake. In contrast, the floor of the Lower Shire valley experiences a meagre rainfall and the climate is tropical. Most of the rain occurs between the

* *The Shire Valley Project:* A Report on the Control and Development of Lake Nyasa and the Shire River. By Sir William Halcrow and Partners, MM.I.C.E., Consulting Engineers, London. Published by the Government of Nyasaland. Price £8/8/-.

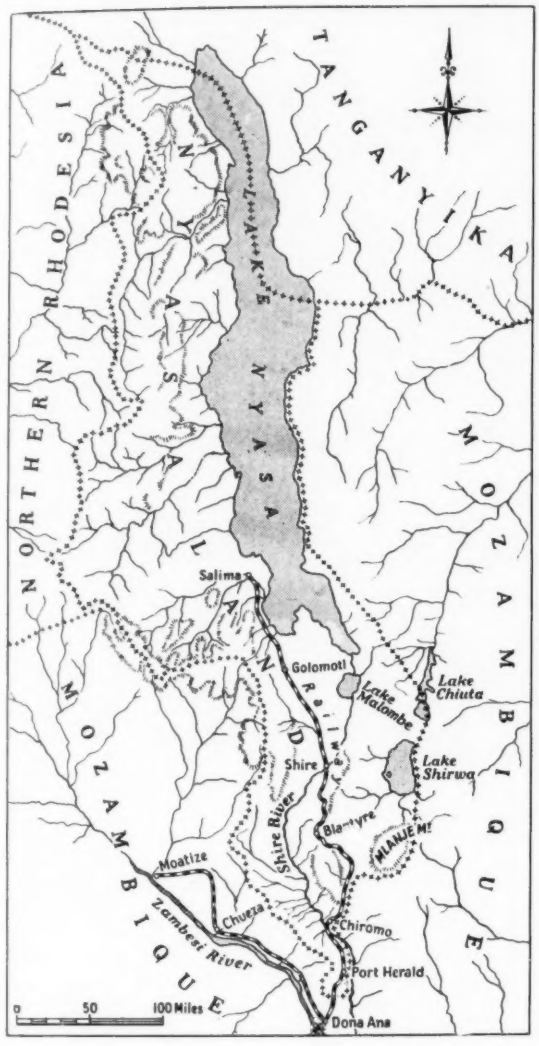


Fig. 1. Sketch map of Nyasaland showing lake Nyasa and Shire River

months of October and April but light drizzles and mists are common in the highlands during the otherwise dry months.

Lake Nyasa is the third largest lake in Africa and has an area of some 11,430 sq. miles; it has a total length of 360 miles, and the width varies from 10 to 50 miles. The maximum recorded depth is 2,300 ft. so that the lake bed, in part, sinks to some 750 ft. below sea level. The seasonal variation in the level of the lake averages from three to four feet, but may be as much as six feet in a single year. Over long periods of years, however, the accumulative rise or fall may be much greater. Unfortunately no systematic records were made before 1896, at which time the level of the lake was gradually declining, until, in 1915, it reached such a low point that the Shire river virtually ceased to flow. At that time the river channel in the upper reaches was blocked by sandbanks and detritus brought down by tributaries in flood, and subsequently covered with a dense growth of reeds. This blockage caused the lake level to rise gradually, until, in 1937, it was 18·6 ft. above the lowest level. The accumulated water then rapidly forced a way through the sand banks and bars and an open channel was once again formed; the Lower Shire valley was largely flooded and has so remained. This reduced the level of the lake to some extent but by 1948 it had again risen to 18 ft. above normal. Since then it has continued to decline and is expected to do so until the conditions favour the deposition of a further series of sand banks and bars. These cyclical alterations of high and low levels suggest a delicately balanced hydrological condition which presents a most formidable problem in the mater of regulating the outflow for power and irrigation purposes.

At present the outflow is governed by the existence of partial bars at the outlet and in the higher reaches of the river. The exit channel has an extremely flat gradient, being in the order of 1:10,000. It is suggested in the Report that the outflow should be controlled to give a minimum regulated discharge of 5,000 cusecs. and this would entail, failing other assistance, the excavation of some 38 million cu. yds. of material

Fig. 2. View of Shire river, looking downstream from bridge at Mpatamanga, showing site of proposed dam

from the higher reaches of the channel to allow this quantity of water to be passed with the lake at its lowest level. Such a solution is not considered practical in view of the prohibitive expense, and two other possibilities are suggested. The first of these would entail the construction of a pumping station in conjunction with a low bund across the lake exit so as to maintain a difference in water level between the upper river and the lake. The power required for pumping would, of course, be insignificant in relation to the power developed in the Middle Shire cataracts; but even so this solution might still require some 8 million cu. yds. of dredging. A further possibility lies in raising the level of the lake to 1,562 ft. above the Shire Valley Project datum, that is, to an elevation some 6 ft. above the 1937 flood level. This would eliminate the need to either pump or dredge but it is understood that the Government is reluctant to sanction a maximum level of 1,562 ft., or thereabouts, until the full implications of the additional flooding around the lake can be more accurately gauged. It would undoubtedly be the simplest of the three solutions from an engineering standpoint.

From the foregoing it will be gathered that the behaviour of Lake Nyasa and the consequential flow of the Shire river, dominate the situation insofar as the reclamation of land and the generation of hydroelectric power in Nyasaland is concerned, but it will be equally clear that the problems presented are far from being insuperable. In point of fact, there is nothing really puzzling from a hydrological point of view in the behaviour of the lake and river. The whole of the free water which flows down the Shire river from the lake, or is stored in the lake, amounts to only 5 or 6 per cent. of the total rainfall of the catchment. This means that 94 to 95 per cent. is evaporated or transpired, or sinks into the soil to maintain the level of the ground water either before or after reaching the lake. In consequence a relatively small change in the rainfall, or in the 94-95 per cent. losses, will result in a large change in the remaining 5-6 per cent. of free water. It follows therefore that the free water available in the Nyasa-Shire system merely follows—only in a highly exaggerated degree—normal variations in the rainfall and other meteoroligical phenomena. For example, the average annual rainfall on the catchment down to Liwonde is about 49 in. If the long average rainfall in this area fell to 45 in. per annum, a reduction of 8 per cent., the Shire would probably cease to be perennial and the lake would diminish in volume. If, on the other hand, the average rainfall increased by 8 per cent. the free water available for storage or outflow might be expected to increase by more than 60 per cent.

There has been a local assumption, developing into a belief, that the control of the outflow from Lake Nyasa would in itself enable large tracts of the lower Shire valley to be reclaimed for cotton and other crops. At present this area is perennial marsh, but it is known to have grown rich harvests in times past. Locally it was considered that the maintenance of the lake near its 1937 level would afford sufficient regulation for this land to be securely redeemed. The report does not consider this view to be tenable. The restriction of the lake level to within a few feet of its 1937 limit, it states, would not allow sufficient water

Fig. 3. Middle River; view taken from left bank at point about 200 ft. downstream of the site proposed for the main dam

to be retained during a wet cycle and this, of course, would preclude continuous regulation of the flow. The total amount of storage would be confined between this upper level and the bed of the river channel, so that only seasonal control would be possible, and in extreme conditions, which might last for some years, sufficiently heavy discharges would take place to cause a return of the swamp conditions in the lower river area.

The Upper River. On this general background the course of the Shire river can now be traced in greater detail. The river leaves the lake about five miles north of Fort Johnston, at which point there is a permanent bar. The river bed appears to shift slightly from year to year and to vary with the level of the lake. Only in periods of very low flow does the reed growth develop sufficiently to cause a serious obstruction. Five miles below Fort Johnston the river enters Lake Malombe, about 18 miles long and 9 miles wide. This lake is quite shallow and there are indications of a slight bar at the exit. For the next 22 miles the Shire follows an extremely flat gradient until it reaches Liwonde, the total fall being only 4 ft. Except in a few places the plain rises very gradually from the banks which are covered with extensive areas of reed growth, often a mile in width and backed by marsh. The channel is generally broad and in its present state varies between 8 and 25 ft. deep, the average velocity of flow being 1·2 ft. per second.

A little downstream of Liwonde the existence of a rock bar had previously been assumed, but borings proved that although some firm rock existed on the left bank, interspersed with decomposed rock, no trace could be found of solid rock in the river bed down to a depth of 100 ft. Downstream of this point there is a sudden change in the gradient of the river, the fall between Liwonde and Chigaru, of Matope, a distance of 36 miles, being 19 ft.

Middle River. In the middle river from Matope to a point about 12 miles upstream of Chikwawa, a distance of about 50 miles, the valley narrows and forms gorges in places; its descent of about 1,260 ft. is marked by spectacular rapids and cascades although there is no direct fall of any magnitude. The main rapids occur at the following places:

1. Matope Bridge on the Blantyre-Lilongwe road.
2. Nkula, near Walkers Ferry, 15 miles downstream from Matope.
3. Tedzani, about five miles below Nkula.
4. Mpatamanga, on the Blantyre-Salisbury road.
5. Hamilton Falls, 12 miles upstream of Chikwawa.

Minor rapids also occur at Nachimbeya some ten miles downstream of Matope. This whole series is generally known as the Murchison Falls.

The Lower River. Twelve miles below the Hamilton Falls the hills recede on either side of the channel to form a flat plain, about twenty miles wide and extending south to the Zambezi. This portion is known as the Lower River and meanders through the plain, creating vast swamps which are partly seasonal and partly perennial. Surprisingly enough, in the 56 miles of its course through the Elephant Marsh to Chiromo

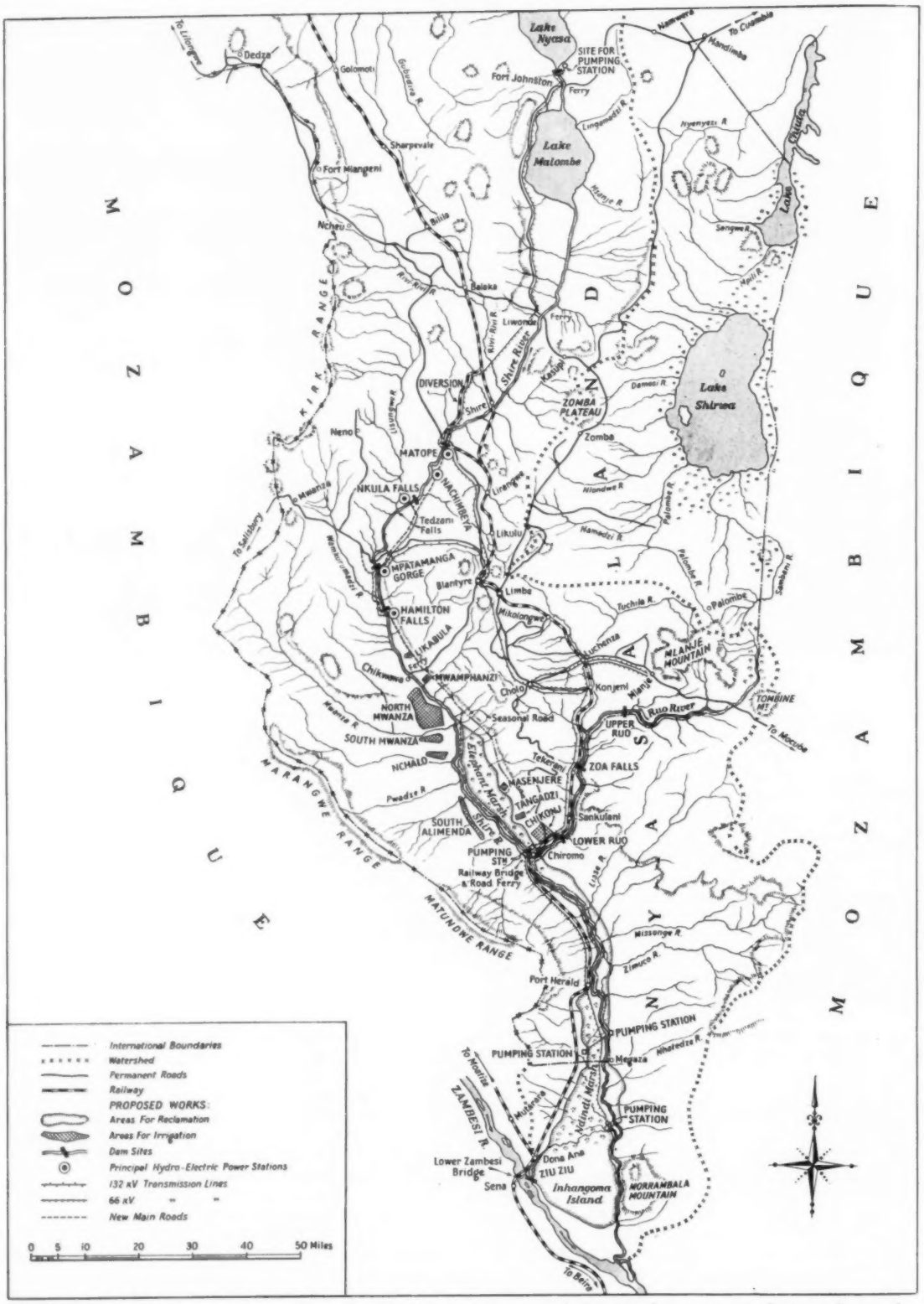


Fig. 4. Map of Shire Valley indicating course of river and suggested sites for dams, power plants and pumping stations and reclamation areas

the water surface of the lower river drops nearly 100 ft., but the channel is so seriously obstructed by reed growth that the flow is split up and diverted into innumerable side channels which form large static lagoons within the swamp area. Several perennial tributaries enter the swamp on the eastern side but make no definite junction with the Shire, their waters simply being absorbed in the swamp. In the area between Port Herald and the Zambezi the picture is complicated by a channel branching off from the Zambezi which, in effect, is an overflow channel that, on occasions, diverts more water from the Zambezi into the Shire basin than this river normally carries. Excepting during flood times, the fall of the Shire from Port Herald to the Zambezi is 30 ft. In times of flood however this differential is reduced to 12 or 15 ft.

Flow in the tributary streams is seasonal and erratic. The wet season (November to May) is responsible for as much as 85 per cent. of the run off. During this period the tributaries may rise and fall many feet in a period of a few hours, causing flooding in the lower

Fig. 5. The Nachimbeya rapids on Shire river as seen from right bank looking upstream

Fig. 6. Shire river at Chikwawa looking downstream from ferry boat

Fig. 7. Bend in Shire river south of Alimenda, illustrating reed growth

reaches. In the dry season flow may cease altogether and although a few of the streams are perennial their flow is greatly diminished. The largest of all is the Ruo which drains an area of nearly 2,000 sq. miles. This area includes most of the watershed associated with Mlanje Mountain and the eastern slopes of the Shire highlands south of Limbe. On parts of Mlanje the rainfall is as much as 130 in. per annum and sudden spates are produced which play a major part in the flooding which takes place in Lower Shire valley.

Conclusions and Recommendations

The consulting engineers believe that the three reaches of the Shire valley present a real opportunity for economic development. The works they envisage are necessarily on an impressive scale but they consider the potential economic and social gains to be of like magnitude. Although these schemes as a whole would be closely integrated the project has the advantage of lending itself to development by progressive stages. Operations on this scale are not as a rule self-supporting in the early stages but they consider this project to be fortunate in that appreciable benefits would result from the very earliest of the works proposed. In this respect they regard the problem presented by the falling level of the lake to be pressing, both for social and technical reasons. After exhaustive examination of all their findings they recommend:

(a) The construction of an integrated scheme for the control of Lake Nyasa and the River Shire, the production of hydro-electric power, the reclamation

Fig. 8. Elephant Marsh in time of flood. (Photo by Rhodesian Herald)

Fig. 9. Aerial view of Shire river, looking upstream, showing Neindi Marsh and Port Herald. (Photo by Rhodesian Herald)

Fig. 10. Elephant Marsh after reclamation; model by Hunting Aerosurveys Limited

and protection of the lower Shire marshes between Chikwawa and the Zambezi, together with an appropriate system of roads and communications.

(b) The development of local irrigation schemes and conservation of existing soils and natural hydrological assets.

(c) The development of industries which would use the natural resources of the area and its hydro-electric power. Suitable industries would appear to be the production of nitrogenous fertilisers to increase the productivity of agriculture and thus the general standard of living; the production of cotton goods from local crops; the production of alumina and aluminium from the bauxite on Mlanje Mountain; the manufacture of paper from the reeds in the lower river; jute and sugar industries and the production of cement.

(d) The raising of the low stamina of the people, which hampers any attempt at betterment, through a programme of improvement of public health and diminution of endemic diseases, and the encouragement of the production and use of more protein foods.

It is considered that this work could reasonably be carried out in stages, the goal being always the raising of productivity and the national income. As a first phase, it is suggested that works should be undertaken which would result in seasonal control over all the Lower River marshes to a considerable degree. These measures alone, they estimate, would result in a great improvement and bring in an appreciable revenue.

It is recommended that this first phase, which might be spread over a period of years, should embrace the following works:

(1) The immediate blocking of all outflow from Lake Nyasa by a seasonal bund at Liwonde. This would allow a detailed exploration of the soils in the lower river marshes and the concurrent use of some of the land in the dry season, stop the lake from falling too low, and facilitate the construction of the various works.

(2) The construction of a barrage and a low-head power station of 30,000 kW peak capacity at Matope, and either the diversion of the existing railway or the reconstruction of the existing bridge and approaches.

(3) The cutting of reeds in the lower river, the opening up of old river courses such as the eastern channel in the Elephant Marsh, together with the improvement by dredging of the River Shire itself.

(4) The closing of the Ziu-Ziu, the Zambezi overflow, by an embankment running from Mutarara south-eastward along Inhangoma Island.

(5) The diversion southwards of the confluence of the river Ruo with the Shire river.

(6) The carrying out of pilot experiments on various forms of irrigation at places such as Chikonji, Masenjere and Nchalo, and on reclamation below Chiromo Bridge and below Port Herald. All intended participants should be associated with these experiments for stimulation of interest and instruction at the earliest possible time.

(7) The improvement of public health by the control of insect and other vectors.

(8) The control by the various Governments of all lands necessary for the implementation of the scheme and the energetic control of the development to the fully productive stage.

The capital cost of the works embodied in the first phase is estimated at £23,631,000 at present prices.

The succeeding phases should include:

(9) The construction of a pumping station at the outlet from Lake Nyasa and improvements in the Upper Shire as or if this is necessary. This would allow the use of a greater volume of the lake for storage and regulation of the outflow if it is desirable to confine the lake level below the 1937 flood level. (If greater latitude were to be acceptable in regard to the top flood level of Lake Nyasa it might not be necessary to install this pumping station at the lake outlet).

(10) The construction of hydro-electric and flood-control schemes at Nkula, Mpatamanga and Hamilton

Falls with a peak capacity, including the small Matope development, of 360,000 kW at 66⅔ per cent. load factor. A grid would also be required and it is estimated that power could be generated and transmitted to main substations at a cost of 0·275d. per kWh. Another large development of up to 75,000 kW continuous may be possible at Matope and should be explored in detail.

(11) The carrying out of such soil and run-off conservation and flood control works as are possible on the Ruo and other tributaries, and the development of hydro-electric power on the tributaries when the electrical grid system is able to accommodate it.

(12) The ultimate reclamation of the lower river marshes from Chikwawa to the Zambezi by flood relief channels, drainage channels, pumping stations and polders.

(13) The improvement of the Lower Shire river to its confluence with the Zambezi and of the Zambezi beyond that confluence if possible.

(14) The insistence on the use of reclaimed lands for the intensive cultivation of cash crops, such as rice, appropriate to the various soils.

(15) The encouragement of other work as well as food growing by the establishment of local industries and reasonable communications with neighbouring territories.

For the power developments alone the capital costs, annual charges and annual income are set out in Table I.

TABLE I. POWER DEVELOPMENTS

	Capital Cost	Annual Charges	Annual Income
Matope low head ...	2,740,000	165,000	
Nkula	9,496,000	570,000	
Mpatamanga ...	10,985,000	659,000	3,290,000
Hamilton Falls ...	7,299,000	434,000	
Grid	6,530,000	457,000	

The consultants state that they are unable to set an exact value to the betterment which will result from the recovery of large areas of land to productive agriculture, from the general raising of standards of living and productivity, or from the opening up of a vast inland water transport system. They maintain, however, that if a small overall profit of 0·1d. per kWh. be taken from the sale of power, and an increment of £18 per acre per annum be taken from intensively cultivated areas bearing, say, rice and £2 per acre per annum taken from other protected or reclaimed lands bearing other crops and livestock, then an annual income of some £5·3 million could be set against the annual charges of the scheme, which they have assessed at approximately the same figure. To this income should be added taxes on the increased population and their increased earnings, taxes on the profits of new industries and improved existing assets, profits on the sales of industrial products which may be developed, the relief of pressure on. and the improvement of, existing over-exploited fertile lands and the release of such lands for the growth of cash crops such as cotton.

Fig. 11. Shire river at Ntundu, looking upstream, at site of proposed Ntundu barrage

Fig. 12. View of Shire river at Ntundu, looking upstream from right bank, showing large sudd island drifting in the current

However the finances of the project are considered, there seems to be no doubt that its implementation would enable Nyasaland to play a very greatly enhanced part in the overall economy of the Federation of Rhodesia and Nyasaland.

The Report goes on to say that it was extremely difficult to put a money value to all the benefits resulting from such a scheme, envisaging as it does a rise in overall standards of productivity and living, with all that is implied by a stable social organisation and the circulation of money. No attempt is made at an inclusive analysis but the Report considers that there are two major aspects to which some sort of value might be set:

The first is that there is available a firm hydro-electric power output of at least 240,000 kW continuous. This represents a total output of 2,100 million kWh per annum and if a profit, after

deducting annual charges, of only 0·1d. per kWh is taken from the sale of the power, then an annual income of some £876,000 would be available to support some other sections of the project which might not in themselves be self-supporting. There is also to be considered the considerable benefits accruing to the territories from the new industries using the power to which no value can at present be assigned.

The second aspect is concerned with the value of the reclaimed and protected marshes and lowlands. The proposals concern the whole of the valley floor from Chikwawa to the Zambezi, for the problem is essentially a single one and the beneficial effects of the various protective works are not restricted to Nyasaland but extend also to Portuguese East Africa. It is only reasonable therefore to presume that the whole of the area benefiting from the works should contribute towards their cost.

Fig. 13. Matope barrage and power station; model by Hunting Aerosurveys Limited

There are approximately 425,000 acres of marsh and low-lying land between Chikwawa and the proposed Ziu Ziu/Inhangoma embankment of which approximately half is in Nyasaland and half in Portuguese East Africa. Some 320,000 acres of this might be taken as the area protected, after deduction for drainage channels, embankments, and other works. Of this, possibly one-quarter might be expected to produce, when water is under command, a crop such as rice, followed by cereals or beans in the dry season. Other cash crops of similar high value might also be grown. The remaining three-quarters of the protected land could accommodate a more diverse agricultural system. There might also be added some 40,000 acres of lands which might be irrigated on the fringe of the valley between Chikwawa and Chiromo.

The present value of rice is £60 per ton, free on rail in Nyasaland. With control of the water it might be expected to produce 0·9 tons of rice per acre or an income of £54 per acre. Of this some £18 per acre might reasonably be the official share to Government after deducting £24 for the grower, £10 for the marketing and milling organisation, and £2 for a reserve fund. The net income, which could be set against the annual charges on the protective works, from such a crop alone would amount to £1,440,000 from an area of 80,000 acres. To this may be added contributions from the other crops, grown on the remaining three-quarters of the whole area, or 240,000 acres, whose value cannot be assessed, but a drainage rate of at least £2 per acre per annum could be taken for the purpose of this analysis. This is the water rate charged in irrigation schemes in Southern Rhodesia and it is suggested that a similar figure be taken for the 40,000 acres of irrigable land between Chikwawa and Chiromo. The contribution from these two types of land might therefore amount to £560,000 per annum giving a total from all types of protected and reclaimed land of £2,000,000 per annum.

One further point is mentioned. All the proposals are for heavy engineering structures on which the annual charges would be largely interest and amortisation on the original investment. If world-wide inflation of currency continues, as it has for many decades, the value of such a project to the owner increases in a striking manner, for the fixed annual repayments on the initial long-term loan are repaid in a depreciating currency, while the benefits from the project in crops, power and taxes should maintain their true value.

Escher Wyss Limited. We extend our warmest congratulations to Escher Wyss Limited, Zurich, who have just been celebrating the 150th year of an activity which began with water-wheel driven spinning machines and soon spread to the manufacturing of water turbines, in which the Company now enjoys a world-wide reputation.

Oued Agrioun Development. We wish to thank *Electricité et Gaz d'Algérie* for the uncommonly well produced brochure and the folder devoted to this important North-African venture, now in full operation. The brochure contains a brief description of the installation (WATER POWER, February 1955, p. 67) and an account of the progress made in the constructional work. There are numerous illustrations; the two full-page views in colour of the exciter and turbine floors of the Darguinah power house are particularly impressive. The main general characteristics of the development are given in the folder, together with an abundance of maps, plans and diagrams.

Archiwum Hydrotechnicki (Hydrotechnical Records). We have received the first issue of this quarterly bulletin published by the Research Institute of Hydraulic Engineering of the Polish Academy of Sciences. The bullein will deal with all questions related to water power, water supply, sea structures and kindred subjects.

The Swedish Diamond Rock Drilling Company have published a brochure describing the Craelius XC range of drills for core and blast hole drilling. The associates of this company in England are the Craelius Co. Ltd., Clarges Street, London, W.1.

The Fifth International Congress on Large Dams

The Fifth International Congress on Large Dams, which is a body associated with the World Power Conference, held its meeting in Paris from May 31 to June 4 last. In this, the final instalment of our series, a report is given on the more important points raised in the discussions of the various papers.

PART THREE

EACH Congress has it own atmosphere which will readily be appreciated by those used to attending international meetings. The atmosphere of the Third Congress on Large Dams (Stockholm) had very much the flavour of an end-of-a-war period. The machinery of the International Commission had just been restarted. Members were thinking in terms of resuming work everywhere, in spite of an uncertain future. New construction methods (Swedish tunnelling methods) and entirely new power-station designs (Swedish underground power stations) were shown to the members, but the feeling was still one of uncertainty. In spite of the grand way the Swedish members entertained their foreign colleagues, in spite of the novelty of what was to be seen during the study tour to the North of the Arctic Circle, the members seemed to be aware that the whole organisation of the International Commission and of the Congresses it sponsored were built on a fragile basis.

The Fourth Congress in New Delhi (1951) marked a period of international expansion. This was the reason for a Congress of this importance being held in India. Several members who had been absent from the Third Congress went to India, and the Indian Government did everything to make the Congress a national success.

The Fifth Congress in Paris was a pause to mark past achievements and to proclaim the faith of all in the stability of this international organisation.

It was decided at the last meeting, on Saturday, July 5, that important papers submitted to the Commission would not have to wait the next Congress for publication but would be printed in a Journal to be published at intervals between the sessions of the Congress. This practical step shows how the administration of the Congress is determined to go ahead.

The opening session on May 31 was an occasion for Mr. A. Coyne, Chairman of the French National Committee and past President of the International Commission, to greet Mr. Hathaway (U.S.A.), the new President of the International Commission. The President of the French Republic being absent from France, the opening session was presided over by the Minister of Public Works. The meeting was also attended by senior representatives of the "Direction du Budget," the "Direction de L'Electricité" and the "Electricité de France."

The three speakers (Messrs. Coyne, Hathaway, and the Minister of Public Works) emphasised, each in his own way, the connection between dam construction and irrigation works, which is one of the oldest crafts in the world, and the possible relief which may be given to hard-working populations by future developments of atomic energy. The Tigris River, the Queen of Saba, and the 3,000 year old "grand art" of irrigation were named in speeches where the possibility of splitting atoms was also mentioned.

Mr. Hathaway said that in 1933 at the First Congress in Stockholm, 21 nations were represented and 47 reports were sent in. In 1955 nations officially represented at the Fifth Congress numbered no less than 40, and 96 reports and 36 communications were sent in. About 1,000 people were attending the Congress, of which about 600 came from outside France.

The second part of the opening session was dedicated to the distribution of honorary awards to past presidents, past vice-presidents and past secretary-generals of the International Commission. This was obviously an occasion to review the whole history of the International Commission from the early days when, in 1927, it was created by Monsieur Gustave Mercier (first president and first honorary president), to the time when Mr. Andre Coyne (1946-52) and then Mr. G. Hathaway took over the presidency.

Monsieur Mercier who, in 1946 restarted the whole organisation, was too ill to attend this session. Everybody regretted the death of Monsieur Arland, the former permanent secretary of the International Commission.

After honorary awards had been given to Messrs. G. Mercier and A. Coyne, the names of Mr. Giandotti (second President of the International Commission), G. Westerberg (vice-president 1946-52) were called, together with Mr. de Tierry (German vice-president), his award being received in his absence by Prof. Press (Berlin). Dr. H. Grunner (Swiss vice-president) was also absent and his award was received by Mr. H. Gicot. Other names mentioned were those of Mr. Savage (U.S.A.), award received by Mr. Vetter (U.S.A. Chairman); Prof. Vogt, Director General of the Norwegian Board of Electricity; Sri. Khosla, former Chairman of the Indian National Committee, now at Roorkee University (award received by Dr. Rao); Mr. J. Hinds; Prof. B. Hellstrom (for 17 years chairman of the sub-committee on concrete); Mr. Genthial; Prof. Aubert, former Chairman of the Compag-

nie Nationale du Rhône; and Mr. Giguet, Director of l'Equipment d'Electricité de France.

Question 16. Design and Construction of Dams on Permeable Soils and Methods of Foundation Treatments

The general report was submitted by Mr. J. F. Rebelo Pinto who spoke in French. He said the reports submitted to the Congress under Question 16 showed the importance of preliminary studies to determine the permeability of the reservoir (Walker, report R.1) and the dam (Uguet Report T.45). The considerable importance of the preliminary work carried out for the 120 m.-high Serre-Ponçon dam was shown in the reports of Maigre (R.79) and of Ischy and Haffen (R.80).

The main problems concerning foundation treatment were the grouting of rock and of alluvium and the consolidation of the foundations. The grouting of the limestone foundations of the Charmine dam (estimated volume of voids 320,000 cu. m., volume of grout used for sealing the fissures 20,000 cu. m.) and the work done at Serre-Poncon were mentioned among many others by the general reporter.

The general reporter said that few new ideas had been submitted to the Congress under the heading of Question 16, but the tools at the disposal of the engineers and the modern methods were more and more powerful. Problems that could not have been solved years ago could be tackled today with the new equipment at the disposal of the engineer, a typical example being the construction of the Serre-Ponçon dam. The grouting of the alluvium foundation to a depth of 100 m., which is now being carried out, would have been an impossible task some years ago.

The first speaker was Mr. R. Davidenkoff (Germany) who commented upon paper R.74 by Dr. Rao. He said that two types of erosion had to be considered. The first type concerned localised water losses flowing along pervious channels inside the dam. This was the so-called regressive erosion, about which very little was known and which could hardly be studied analytically. The so-called rules of Bligh and Lane referred to this type of erosion. The second type of erosion was ordinary piping, as studied by Terzaghi, Rao and others. Comparison between the coefficients of Bligh and Lane with the figures obtained for piping were not conclusive.

Davidenkoff and Baumgart published a paper in 1929 in Russian. In this paper the stability of an element of soil at the base of a vertical impervious pile was considered. Harza, Terzaghi and Bazant have given formulae for piping which compare with the values published by Davidenkoff (case of one single vertical pile): According to Davidenkoff if the critical head by Harza-Rao is 1·00 it will be 0·81 by Terzaghi, 0·70 by Bazant and 0·64 by Davidenkoff-Baumgart.

In his answer, Dr. Rao mentioned different types of foundations on permeable soil. Some American dams were provided with a positive cut-off by sinking reinforced-concrete caissons through deep alluvium exceeding 250 ft. in depth. Experience of Fort Peck showed that a single sheet pile could not be relied upon and that subsidiary devices like relief wells on the downstream side were necessary. Several dams in the U.S.A. and in Sweden were provided with a horizontal clay blanket. The 300 ft. deep grouting for the Serre-Ponçon dam was an experiment, the success of which would remain to be seen after the dam was built. In India both sheet-pile cut-off and upstream blankets were much used in the construction of earth dams on approximately 80 ft. depths of sand river beds. Concrete structures up to 30 ft. in height on permeable foundations had been built more recently, e.g. the Nangal dam, 90 ft. high, was built on perious foundations consisting of conglomerate rock intermixed with clay. The structure itself was designed as on permeable foundations. The only other structure of this type was the Jajce dam in Jugoslavia (see R.20 by S. Mikulec), which is provided with an upstream concrete blanket, a downstream sheet-pile cut-off, and an upstream "grout cut-off."

Mr. Laginha Serafim (Portugal), a well-known specialist of arch-dam design, said that he used a method similar to the one developed by Dr. Rao for the computation of flow diagrams in anisotropic materials.

Mr. Duquenois indicated that he was using the silt transported by the river to clog the pores of pervious alluvium. With a 15 h.p. motor the silt deposited at the bottom of the river was put into a state of turbulence. Additional information on R.79 and 80 on the Serre-Ponçon dam foundations were given by the authors of these two papers.

Question 17. Economy and Safety of Different Types of Concrete Dams

The general reporter, Mr. A. Coyne, after summarising a brilliant report, kept the spirited discussion going to a lively rhythm by calling directly on his supporters an opponents to give their opinion. The discussion on question 17, with its rather dull title, became like a lively game, thanks to his forceful personality. His interest in arch dams and thin arch dams is, of course, well known.

Alone among the European contributors, he stated Mr. H. Juillard, judging the particular case of the Oberaar dam, maintained that the expense of the deeper excavation, a certain consolidation of the supports, higher cement content and other extra work, would have absorbed the whole of the savings on an arch dam, as opposed to a gravity dam. He was, however, contradicted by a great majority of authors, and, as Mr. Coyne concluded: "arches, whenever they can be built, ought to carry the day from the point of view of both safety and economy."

In France the total increase in the cost of concrete for an arch dam was about 15 per cent. whereas the savings in volume would be from 30 to 60 per cent. and even 85 per cent. in the particular case of the Gage dam. Thus the cost of a standard arch dam was established as being between 70 and 40 per cent. of that of a gravity dam capable of fulfilling the same function.

In fact, what added to the cost of a slender or lightened structure, particularly when viewed through American eyes, was not the additional cost of the cement or the formwork, but the slower building rate resulting from the various requirements inherent in the reduction of the volume. The Portuguese had analysed the cost per cu. m. of concrete and published the following figures:

6,600 fr. per cu. m. for a thick arch of 460,000 cu. m.
7,500 fr. per cu. m. for a thin arch of 360,000 cu. m.

11,200 fr. per cu. m. for a thin arch of 50,000 cu. m.

In his conclusions Mr. A. Coyne states: "While the notion of economy is a fairly clear one, we have seen that safety is not so easily defined, since different criteria must be used for evaluating each type of dam, and that we must therefore be content with the concept of adequate safety."

"There is, however, one thing which would be of great help to designers, particularly regarding the margin of perfectibility of each type of dam, and that is wide publicity for experimental results. Small-scale-model tests have given useful information. Why not also publish the results of systematic long-term measurements and observations carried out on the dams themselves? Comparison of these with calculations and tests ought to reduce that margin of ignorance which is called the margin of safety, and which may well cost too much without even providing the guarantees which people expect from it."

Mr. C. Marcello (Italy) stated that he had designed and built twelve hollow gravity dams in 15 years, four of them being still under construction and several of them at an altitude of between 6,000 and 7,000 ft. (2,000 m.). One of them, now under construction, was 111 m. high (volume of concrete: 350,000 cu. m.). The foundations were on fissured sandstone, clay and marl. Grouting was necessary to consolidate the rock and a modulus of elasticity of 75,000 kg. per sq. m. was reached. Another dam built above an elevation of 6,500 ft. had a height of 260 ft. (80 m.) and a volume of 40,000 cu. m. Measurements had shown the uplift to be negligible. No cracks had been observed in the concrete. He concluded by saying that the financial saving for a hollow gravity (buttress) dam as compared with the gravity type was estimated to be 20 to 30 per cent., the saving in the volume of concrete used being 35 per cent.

Mr. Xeres (Portugal) agreed with the summary by Mr. Coyne and the conclusions of his report. He said that the safety of big arch dams was more than what was really required. Much additional information could be gained by measurements on existing dams and by tests on models. But all the laboratories should use techniques which could be compared for easy analysis and discussion of the results.

After Mr. Roberts (Great Britain) commented on his paper R.12 on the heightening of a gravity dam (Mullardoch dam), Mr. Semenza (Italy) mentioned the Pieve di Cadore dam with the very high ratio L/H = 6. He thought it would be possible to design dams for L/H = 8 or even 9. One recent Italian dam had a ratio of L/H = 7.

In one case mentioned by Mr. Semenza the foundation rock was too plastic. After consolidation by grouting the modulus of elasticity E was increased from E = 25,000 kg. per sq. cm. to 50,000 kg. per sq. cm. He had also built a dam where the rock quality for foundations and abutments varied from "very poor" to "very good." This inhomogeneity of the rock was not a maior difficulty for the dam designer. He considered that the symmetry of the abutments on both sides of the arch was not an absolute requirement but a symmetry would cause higher strains and possibly a more costly arch. With the help of model tests, there was no difficulty in designing asymmetrical arch dams. Continuity of the rock contour was more important than symmetry. Sharp discontinuity should be avoided. An arch dam was tested in the model stage with no foundation at its base; it stood. An actual 21 m. high dam, built on its foundation platform, stood up to a dangerous flood overtopping the dam when the joints were still open.

A swedish specialist on dams states that the Swedish State Board estimated the pressure due to ice to be 40 tons per sq. m. This was also the figure proposed by the Bureau of Reclamation (U.S.A.) and it was added that it could prove to be dangerous for low-head dams.

Mr. Banks (Great Britain) estimated that a reduction amounting to 40 per cent. by volume of concrete was achieved at Allt-Na-Lairidge dam with the prestressing method used. Taking into account the cost of the high-tensile steel and of the prestressing the estimated financial economy was about 10-15 per cent.

Mr. Hassam Zaki (Egypt) emphasised that Egyptian engineers had built several massive dams pierced by sluices. They were all masonry dams as Egyptian engineers did not trust concrete dams, where the concrete would be liable to shrink. Masonry, on the other hand, would show microscopic cracks only. After the second heightening, the Aswan dam had proved to be in a very satisfactory state. The solid dam section was in a far better condition than the pierced section, owing to the vibration and cavitation of the sluice gates.

After Mr. Pinto Machado had introduced the discussion from the Portuguese side, Mr. M. Rocha (Portugal) said that the crushing strength of the rock on site, where lateral compression was always possible, was higher than the figures obtained in the laboratory. The local variation of the modulus of elasticity, which could vary from 20,000 to 200,000 kg. per sq. cm., had proved not to be dangerous for arch dams. Observations on the prototypes and tests on models had shown that the arch dams adapted themselves to varying values of E.

He stressed the importance of model tests, especially for arch dams, and said Portuguese engineers were studying the strains and stresses in membranes, as a basis for arch-dam design, and were going in for extensive measurements on prototypes.

Dr. Rao (India) said that gravity dams and arch dams were really supplementary. At Bhakra dam for instance the left abutment was not strong enough for an arch dam.

Mr. H. Juillard (Switzerland) described the Ober-Aar dam which was of the hollow gravity type. About 14 per cent. was saved in volume of concrete as opposed to a convential gravity dam. The construction in winter of an arch dam, with joints grouted, would have lasted a year longer and have caused a corresponding loss of kWh produced. He insisted that the strains and stresses developing in the foundation rock might become dangerous for arch dams with values L/H = 5 to 7.

Mr. Coyne, who had been taking a lively and personal interest in the discussion, and who had several times stressed the advantages of the arch dams, pointed out that the conclusions arrived at by Mr. Juillard were directly opposite to the conclusions reached by Mr. Semenza. He added that a sharp fault in the rock, with abrupt discontinuity, might be an indication that a gravity dam was the right solution.

An arch dam was easily able to absorb limited local variations of rock strength and rock elasticity, and mentioned that one of the abutments of the Castelo do Bode arch dam had moved by as much as 18 mm., also an arch dam in Morocco had moved as much as 20 mm. and that neither had suffered. These remarks by Coyne were echoed by Messrs. Rebello Pinto (Portugal) and Semenza (Italy).

Other contributors to this section were: Messrs. *Beceril* (Spain), *Groener* (Norway), *Fries* (Norway), *Yirousek* (Czechoslovakia), *Jezdik* (Czechoslovakia), *Hammond* (U.S.A.).

Question No. 18.—Settlement of earth dams due to the compressibility of the dam's materials or of the foundation. Effect of earthquakes on the design of dams.

Twenty-seven reports were submitted to the Commission under the heading of No. 18 question and were dealt with by the general reporter, Professor *Dino Tonini* (Italy) who spoke in French.

The reporter divided his report into nine chapters under the following subtitles:

Chapter I: Foundation consolidation beneath earth and rockfill dams.
Chapter II: Foundation consolidation of concrete dams.
Chapter III: Rock foundation settlement and deformation in concrete dams.
Chapter IV: Displacement of the sides of the valley under the influence of hydrostatic pressure.
Chapter V: Settlement of materials in earth and rockfill dams.
Chapter VI: Concrete settlement in dams.
Chapter VII: Problems relating to the construction of dams on certain soils.
Chapter VIII: Effect of seismic load on the structure of dams.
Chapter IX: Final considerations.

The general reporter dealt very extensively with all of the 27 reports submitted to him. In the final considerations he dealt mainly with rock settlement and its effects on arch dams, on the seismic investigation of the foundation, and on the exchange of data and information.

He considered that "thin arches are little affected by settlement since their static behaviour is comparable with that of triple-hinged arches, while thick arches rapidly tend towards theoretical values corresponding to arch-beam behaviour. Consequently, it is possible to build dams of the arch type on rocks showing a certain elasticity, provided a thin-arch design with wide angular measurements is adopted, even though more extensive excavations are involved. Another result is that arches of varying thickness should be preferred to arches of constant thickness when severe settlement is expected at the abutments. In this case, structure rigidity will be increased in regions of lesser eccentricity and the dam will be made more elastic at the crown where settlement causes greater moment. This is particularly important in the case of lower arches which have necessarily a lower radius-to-thickness ratio and a small angular measurement."

Commenting on seismic investigations, Dr. Tonini was of the opinion that "A modulus, actually a non-localised statistic average value of the regional moduli, can be determined quickly and economically by means of the tests described in the reports. It is agreed that seismic tests give a dynamic modulus for zero load conditions which bears simple correlations with the normal static modulus and that it can advantageously replace that static value since not alteration of the rock is involved during examinations."

These reasons have led to a recommendation suggested by Mr. Semenza in a recent report that rock classification should eventually be made in terms of a quality scale, such scale being based on the considerable data gathered on the dynamic moduli of a wide variety of rocks of effectively known characteristics. Classification and comparison would be greatly facilitated and speeded up. Such classifications could be made in relation to time factors (eventual deterioration of the coefficient due to cyclic reservoir conditions and atmospheric variations), a provision which, with other methods, is applicable only in specific cases.

Finally, Dr. Tonini proposed that "the International Commission for Large Dams should be responsible for the promotion of live exchanges of data, even though the results may not yet possess the degree of perfection and interpretation of a formal communication."

Mr. Marcello mentioned a 110 m. high buttress dam, the settlements and deflections of which were carefully measured; five pendulums were built in. triangulation and alignments were checked, and angular deflections and uplift measured. The dam proved to be perfectly elastic, the deflections going back to nought when the reservoir was emptied. The modulus of elasticity of the rock was found to be 75 kg. per sq. m.

The same author then described a dam 75m.high in Sicily, built on compressible and unequal foundations. Because of local conditions, a convential earth or rockfill dam was impossible, as the width of the foundation basis for such a dam would not match the local topography of the steeply inclined valley. In consequence he replaced the loose rockfill material by precast concrete blocks, having a rectangular cross section 4 m. square. The blocks were piled one above the other with the 0·30 m. wide joints between them filled with the gravel. The proportion of voids was far less than with a conventional rockfill dam, the upstream and downstream dam faces were far steeper, the crest deflection and the settlements reduced. The total settlement was as little as 2 per cent. The unit price of the dam was 3 to 3·5 times the unit price of rockfill but the volume of the dam was only one fourth of a conventional design.

Several authors from Yugoslavia and Czechoslovakia brought additional information on rock settlements, dam deflection, rock settlement due to the weight of water, and the different values for the modulus of elasticity. Some doubt was cast on the advisability of using the dynamic modulus of elasticity, especially on clayish material. This provoked a remark by the general reporter, Mr. Tonini, who established that both the dynamic and the static modulus of elasticity were useful conventions and that they were correlated to each other.

Mr. Chamberlin (Algeria) reported on the earth quake of Orleansville. In this the *Oued Fodda* dam

at 30 km. from the earthquake centre did not suffer any damage, but in a second dam, 70 years old, at 5 km. from the centre, which had to stand a shock in the direction parallel to the crest (force 8-9 of the earthquake scale) the right abutment moved by 50 cm. relatively to the left abutment. Two kilometres downstream the relative movement of the river banks was about 2·5 m. It was likely that the whole dam had been displaced together with the whole valley, in view of the limited damage done to the structure. The nearby gallery was severely damaged.

Mr. Serafim (Portugal) reported on the displacements of the Portuguese dams (Castelo do Bode, Cabril, etc.) and Mr. Lane (U.S.A.) reported on Garrison dam, where the modulus of elasticity of the foundations was 1,000 to 2,000 kg. per sq. cm.^{2} only, with settlements of the order of 2 ft.

The measurements will be published later.

Question 19. The Relation of the Cement Content of the Concrete to Performance in Practice of (a) Gravity Dams (interior and exterior), (b) Arch Dams,(c) Buttress Dams, and its Influence on Permeability and Frost Resistance

Dr. F. M. Lea, the general reporter, dealt authoritatively with the twenty reports that were submitted to him. His own general report dealt with the following subtitles:

1. List of reports submitted.
2. Report of the international subcommittee on concrete for large dams.
3. Review of practice and of the behaviour of actual dams.
4. Laboratory studies of permeability and frost resistance.
5. Relation between laboratory tests and field experience.
6. The role of cement content.
7. Points suggested for discussion.

The report of the international subcommittee is primarily a report to Congress of the work of the subcommittee. It consists of a number of individual papers.

Concerning the role of cement content, the reporter stated that while the comparison of concrete with the same aggregate and the same workability, but with differing cement contents, was of considerable value in selecting a mix for use in a particular dam, the general evaluation of frost resistance and permeability in terms of cement content alone presented difficulties, as both these properties were very largely influenced by the water content of the mix. It was clear that the water requirements would be affected by the quality, shape and grading of the aggregate and any improvements in the latter would be reflected in a reduced water content, and hence a reduced cement requirement.

Discussion of the mixes used in particular dams must also take account of the conditions obtaining at the dam as they affected the requirements for frost resistance and impermeability, e.g. climate, aggressiveness of water, water head, thickness of dam or of upstream facing.

It was nevertheless of interest to note the considerable variation in the cement contents quoted for particular dams or in the reviews of practice in the reports from different countries. For the hearting mixes of massive gravity dams the contents varied from 230 lb. per cu. yd. (136 kg. per cu. m.) or even 188 lb. per cu. yd. (11 kg. per cu. m.) with air entrainment, up to 376 lb. per cu. yd. (223 kg. per cu. m.) without air entrainment. It was even more difficult to distinguish world trends in the cement contents in arch and buttress dams although there was a natural tendency in any one country for them to be greater than in massive dams of the same country. In the case of arch dams, the figures quoted varied from an overall average of 548 lb. per cu. yd. (525 kg. per cu. m.) in one country, down to 278 lb. per cu. yd. (165 kg. per cu. m.) for a particular dam in another.

The reporter suggested the following points for discussion:

(a) The extent to which the usual requirements for minimum permeability can be assured if lean mixes are used for the hearting concrete, or under what circumstances it may be relaxed.
(b) The relative importance of the cement content, the water content and the water-cement ratio, in determining the frost resistance and permeability of concrete with and without air entrainment.
(c) The influence of fine sand, distinguishing between the different sieve sizes, on frost resistance and permeability.
(d) The effect of air entrainment on the design of mixes for minimum permeability.
(e) The extent and mode of attack by aggressive water on modern concrete dams and the extent to which this risk must influence the choice of concrete mixes. The deductions to be drawn from laboratory tests on permeability and frost resistance as to the durability of the concrete in dams in practice.

The discussion following the remarkable report by Dr. Lea was lively but inconclusive. Mr. Price (U.S.A. Bureau of Reclamation) was much in favour of wetting agents. He stated that the latest results showed how the cement content could be reduced even more than indicated in his paper. He insisted that concrete must be as strong as it was when building the Hoover dam. He also declared that fly ash from coal-burning electric plants was being used with success in the U.S.A. Mr. Ros junior (Switzerland) reported on systematic tests made for Mauvoisin and Grande Dixence, in regard to reducing the cement content by the addition of air-entrainment agents, the control of fine sand (less than 1 mm.) and the addition of pozzolanas and fly ash. Dr. Rao reported on conditions in India.

The conclusions of Messrs. Chapelle and Orth (both from France) were on many points different from, and sometimes in obvious opposition to, the conclusions of Mr. Price. Mr. Chapelle reported on the blast-furnace cement used at the dam at Bort. He said that the mineralogic structure of fly ash might vary from one type to the other, according to origin, and this would explain why they reacted differently with different cements. Mr. Orth pointed out how results obtained at the research laboratory from Albertville were influenced by the origin of the cement and by the origin of the aggregates.

Results obtained in French laboratories showed that all the possible variables (cement, fly ash, quality of aggregates) were interdependent and that many

results obtained were somewhat puzzling. He recommended further studies on the whole problem, but agreed with the general conclusions of the report by Dr. Lea.

Mr. Direckx (France) stressed the importance of three-axial tests on concrete samples and Messrs. Ros and Serafin emphasised the same points as being of great importance in dam design.

Conclusions

During congresses of this kind social contacts are of great importance. Paris is an ideal town for entertaining the members. On the first afternoon a champagne cocktail party afforded an admirable opportunity for the members of the various delegations to meet one another. On the second evening Electricité de France invited the members to a brilliant evening performance of the "Corps de Ballet" at the French National Opera.

A second cocktail party was offered to the Congress on the boats which took the members along the river Seine. The last evening was spent at Versailles where the delegates could appreciate the quality of French cooking, the brilliance of a French orchestra and the magnificence of the Royal Chateau de Versailles. Paris, in June, was at its best and every delegate could enjoy the clear sky, the beautiful gardens and the elegance of the city and its inhabitants.

We offer the organisers of the Fifth Congress on Large Dams our thanks for the reception they gave to all members and our congratulations on the outstanding success which they achieved.

Correspondence

The Future of Combined Wind and Water Power

To the Editor of WATER POWER

In connection with the article you published in your April, 1955, issue by Mr. Percy H. Thomas commenting on the paper on wind power which I read last year to the Brazil Sectional Meeting of the World Power Conference, I should like to make some supplementary observations.

The objective of my paper was to draw the attention of engineers and economists to the possibilities of wind power, especially as it is most often regarded as an unmanageable form of energy of low value. I tried to show that in the particular case of the valley winds in Algeria the combination of wind power with hydro-electric power could lead to a harmonious correlation which would fit into the load curve of the system.

Mr. Thomas has developed this theme, and has shown that the case of Algeria was not a special one, but that, in particular, the analysis of U.S.A. meteorological data would seem to show that a small hydro-electric reserve would suffice to compensate for the variations of a wind-power network.

In addition, M. Serra (Chef du Service Hydrologie à Electricité de France) in an article in *Météorologie*, October-December, 1953, showed, amongst other things, that potential wind-power and water-power resources were almost ideally complementary, during the course of the year, from the standpoint of supplying the electrical network of metropolitan France.

These various conclusions combine to show that wind power, when suitably associated with water power, should no longer be regarded as an unmanageable source of energy possessing only the firming-up value of thermal power used in place of wind power in conjunction with hydro power. It is these considerations which have led me to estimate that reliable wind-power generating sets costing not more than £70 per kilowatt installed could be regarded as economic. This figure applies to Algeria—a country poor in fuel and hydro-electric power. Obviously it should be modified in accordance with the cost of power in the country concerned. It would be appreciably lower in countries with ample hydraulic resources or with an abundance of natural gas.

The utilisation of wind power is a problem of the future, and the appearance of atomic energy must inevitably be taken into account. At first sight atomic power would seem to destroy the outlook for the development of wind power on an industrial scale, but an analysis of the future functioning of a network supplied partly by nuclear stations shows that the full-load and peak-load kWh will have a value at least as great as obtains at present. In these conditions the power produced by the wind during full load and peak load will always have a high value if it forms a guarantee for the supply from hydro-electric developments.

We thus arrive at the following conclusions:—

(1) The appearance of nuclear energy should not cause the abandonment of wind-power research. Nevertheless, to determine the commercial value of wind power a clear distinction must be made between power produced by day and that produced by night.

(2) Hydro-electric developments will have to be conceived in terms of firm power, that is to say, provided with suitable storage and with reserve plant capacity, the limit of reserve plant capacity being determined only by transport costs.

H. DUQUENNOIS.
Chef du Service des Etudes Générales et Recherches à Electricité et Gaz d'Algérie.

John Fowler and Co. (Leeds) Ltd. have published details of the Fowler Challenger 1, 3 and 4, crawler tractors.

Road Forms. A coloured leaflet, BK-216, received from Blaw Knox Limited, illustrates and describes the steel road forms this firm produces for all kinds of concrete road construction and for laying large areas of concrete.

Outdoor Oil Circuit Breakers. Catalogue S112 received from Cooke & Ferguson Limited describes their OD2 type outdoor circuit breaker which has been fully short-circuit tested up to 250 MVA at 11 kV. It can be fitted with hand, spring or solenoid operating mechanisms.

Lasele Turbines. In connection with our series of articles " Developments in the Ångerman Catchment " we greatly regret a misprint in the caption to Fig. 40 on page 298 of our August issue in which, by an inversion of the figures, the head of the Nydqvist & Holm 87,200 h.p. Kaplan turbines was given as 25 m. The correct head of 52 m. is given in the text on page 299. This high head is of special importance as it constitutes a record for a Kaplan turbine installation in Sweden.

Models of Hydraulic Structures

After illustrating the theoretical basis of scale models, the author discusses some of the practical problems encountered. Experiments carried out on three scale models for hydro-electric schemes are described

By DAVID H. KENT, M.A., A.M.I.C.E.

PART TWO

THE Owen Falls Dam and Power Station, now being constructed for the Uganda Electricity Board, are situated on the White Nile, just downstream from Lake Victoria. The lake is so large that there is no such thing as a sudden flood down the river —it takes years for the lake level to rise or fall one metre. (In fact 20,000 cu. ft. per sec. flowing in for one year would only raise the level 1 ft.) However, to comply with irrigation requirements downstream, it may sometimes be necessary to discharge 42,000 cu. ft. per sec., and this is to be passed through six sluiceways, each 3 metres wide by 5·1 metres high (about 10 ft. by 16 ft. 9 in.).

Three models were made[15] in the Hawksley Hydraulic Laboratory of City and Guilds College: two by the consulting engineers and one by the contracting engineers. The first, at 1 : 60 scale, was of the whole dam, including the six sluiceways. (Fig. 13). The next was of a single sluice at 1 : 30 scale; and the contractors' model of the dam area was made at 1 : 100 scale.

(a) *Surges*. Some slight intermittent surges had been observed at the bend in the natural river, and it was thought possible that the operation of the sluice gates might enhance and regularize these to proportions which would affect the turbine governing, because of periodic tail-race fluctuations.

Water levels were therefore obtained, for 30 sec. at a stretch, at several points on the 1 : 60 scale model, by means of a balsawood float recorder. This has a vertical aluminium foil rod running in rollers, with a needle point at the top. A smoked glass plate was moved steadily across the needle and recorded the fluctuations in level. Quite large isolated surges were recorded, and these were partially eliminated by

Fig. 13 (above). The six Owen Falls sluices discharging together on the 1 : 60 model

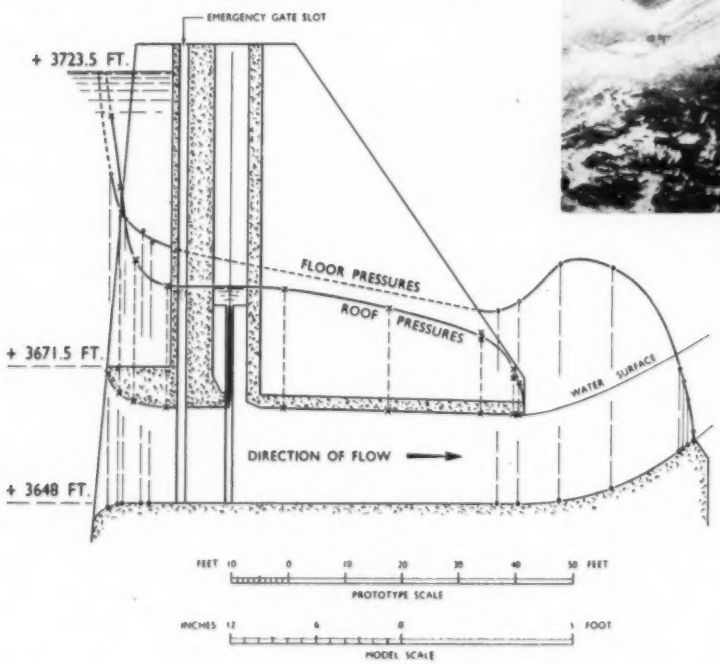


Fig. 14 (left). Pressures on the floor and roof of a sluiceway, as found from the 1 : 30 scale Owen Falls model

means of excavation in the river bed; but no regular movement was found.

Water velocities at important points were measured by means of 1 in. diameter wooden propellers with one blade white and one black. The number of revolutions in, say, 20 sec. could be counted.

(b) *Calibration, Losses and Pressures.* A single sluiceway was constructed in Perspex and wax to a scale of 1 : 30, so that a more accurate calibration might be made, the flow pattern studied, and, most important, the pressures on roof and floor found (Fig. 14).

Static pressure tappings were made in the Perspex, but round the curved wax inlet and the curved bucket it was found convenient to use a search tube (Fig. 15) This was simply an $\frac{1}{8}$ in. brass tube with a tapered, plugged end and a hole in the side about an inch from the end.

In order to check on the effect of the roof and the bucket, several traverses were made at the end of the roof with a "total-head" Pitot Tube. This showed that

Fig. 15 (above). Owen Falls 1 : 30 model. Total-head and static-pressure search tubes, and pressure-tapping points

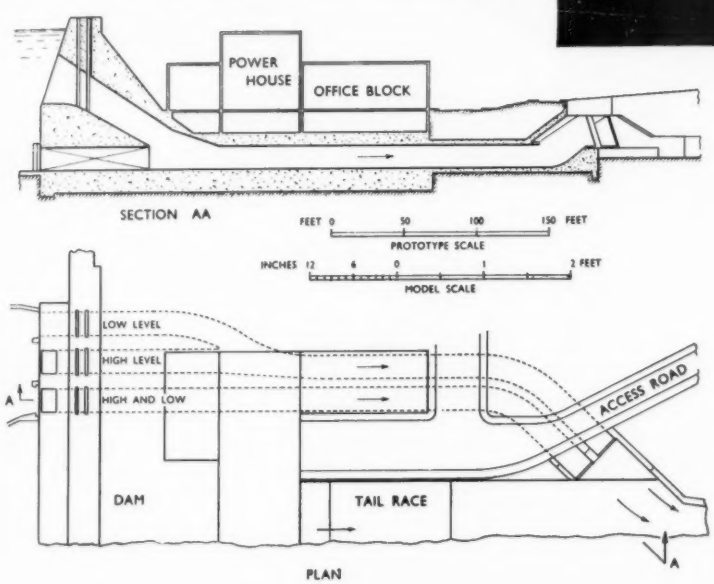


Fig. 16 (left). Atiamuri project—preliminary design of spillways, draw-off sluice and temporary culvert

the coefficient of discharge was low mainly because of the back pressure, caused by the roof extending so close to the bucket; the losses from other causes were normal.

(c) *Conditions during Construction.* The 1 : 100 model was made to try out the effect of the scheme of cofferdams to be used during the construction of the dam. The hydraulic conditions to be expected at each cofferdam could be found and the construction adjusted accordingly. Velocities were measured by observing the deflection of a bead suspended in the flow.

The dam structure itself was also added in stages, so that water levels could be checked.

Atiamuri Spillway Model

The Atiamuri combined Dam and Power Station, now being constructed by the New Zealand Ministry of Works, is one of a series of stations being built along the length of the Waikato River in the North Island, New Zealand.

The flood spillways at Atiamuri lead into channels which pass the water beside the power house and under the office block and then discharge it back into the river downstream of the tail-race (Fig. 16). The spillways, the culverts and a length of river downstream were modelled to a scale of 1 : 60 (Fig. 17), and also the low-level draw-off sluice leading into one of the culverts. Much of the construction was in Perspex. The flow to the model was measured by means of a Venturi meter, calibrated with a measuring tank.

(a) *Design of Channel Bend.* Apart from calibration and the investigation of the general flow pattern, one of the main problems here was to adjust the curve on the outfall end of the culverts so that the water is discharged safely without the culverts having to be heightened too much at this point.

The flow being at well above critical velocity, waves are set up at any corner, positive at the outer wall, negative at the inner wall; and these, together with the centrifugal forces, give a big difference of level across the culvert at the bend. With a 50 ft. mean

radius on the 16 ft. wide culvert, the water level rose 25 ft. at the outside wall above the mean entry depth of 14 ft.

Other radii gave these results.

Bend radius (mean) ft.	50	100	200	300	300-800-400
Max. rise ft.	25	16	8·5	7	4
Max. depth ft.	39	30	22·5	21	18
Distance of maximum from tangent point ft.	70	80	80	75	constant from 75 to outfall

Little research has been published on this subject, but calculations based on a recent work[16] gave good correlation for the height of the wave, but not for its position. The error may be due in part to the effect of the slower-moving boundary layer, for the channel is relatively deep and narrow and the boundary-layer thickness is appreciable—some inches on the model. A paper[17] just published may also help to explain the wave forms as it considers deep channels.

At first the culverts had flexible celluloid sides and no roof, so that curvature could be adjusted until it was satisfactory. A more rigid and accurate culvert was then made to the final design and tested comprehensively.

(b) *Air Entrainment.* When the prototype spillway is operating, the water in the culverts will have a velocity of about 70 ft. per sec. At this speed, a considerable amount of air is drawn with the water and may be entrained at the surface, with consequent frothing and bulking.[18, 19, 20] On the model, the surface-tension force is relatively much too great—some 3,600 times in this case, since σ_r should $= l_r^2$, but in fact equals 1—and practically no entrainment occurs. Thus, from this point of view, the model may give channel sizes which are optimistically small, and an allowance may have to be made. The point at which serious entrainment starts seems to be that at which the boundary layer has grown right to the surface. Fortunately it is, therefore, usually less marked at the deeper, maximum flows. In adjusting the model shape, the best that one can do is to eliminate surface waves as far as possible, and thereby ensure a minimum amount of air entrainment on the prototype.

Fig. 18. Actual sluices discharging at Owen Falls, Uganda, though not under full head. Cf. the smooth model jets in Fig. 13

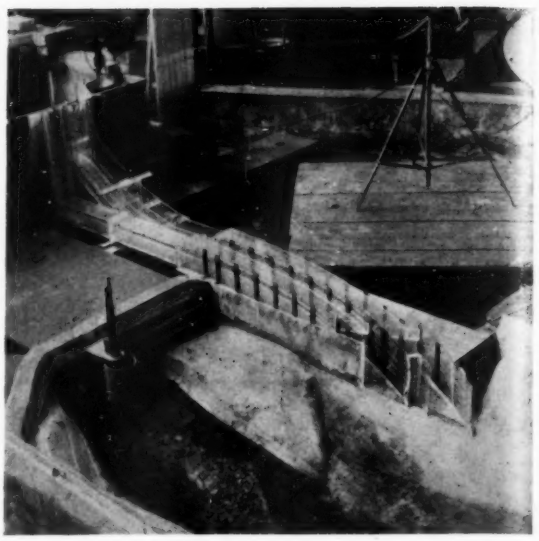


Fig. 17. The Atiamuri model, showing the final design tested on the 1 : 60 scale model

(c) *Scour.* For the same reason—that is, surface tension not being to scale—the discharge jet on the model continues as solid water; whereas on the prototype the air resistance at the much higher velocities can easily overcome the surface tension, and the outside of the jet tends to break up into spray. Clearly, the scouring effect of the completely solid jet is the greater, and in this respect the model is pessimistic. Fig. 13 of the Owen Falls model jet may be compared with Fig. 18 of the full-sized one.

Conclusion

Nowadays most new hydraulic structures are tested beforehand by means of a model. The theoretical background and some methods of carrying out tests have been mentioned, and it has been shown that many hydraulic problems can be solved by means of models. Some difficulty may arise, however, when pronounced vortex, air entrainment or boundary-layer effects are present on prototype or model.

Good results may be obtained economically and quickly, provided that the model is well designed and its possibilities and limitations understood. The overall cost of a model may be only about 1/200th of the cost of a large structure—a very small investment compared with the possible financial savings or the added certainty of design which may be obtained. But it should be emphasized that it does take time to make an accurate model and test it carefully, and the decision to make one should be taken as early as possible so as to leave time. This also makes it possible to get all the necessary data, including comprehensive stage discharge curves, from the site.

Acknowledgments

Acknowledgment is made to Mr. J. Guthrie Brown.

(Continued on Page 347)

Some Geological Aspects of Catchment Areas and Reservoir Sites

By DR. J. E. RICHEY, M.C., F.R.S., F.R.S.E.,
Consulting Geologist, Edinburgh

PART TWO

SUPERFICIAL deposits, the "soils" of the engineer, are insidious causes of leakage from reservoirs, and are among the most difficult to recognise; all "soils" in the vicinity of top-water level, wherever this level comes near to the top of a slope, have therefore to be closely investigated. The main conditions liable to lead to leakage are the following: (1) deep residual soils and deeply weathered rock at low places in the sides of reservoirs; (2) permeable infillings of rock-bounded valleys along one side of which the river to be dammed is flowing; (3) permeable infillings of narrow, often gorge-like river-cut channels in rock, which are of common occurrence in recently glaciated areas such as the British Isles north of a line drawn from the Bristol Channel to the Thames estuary; (4) permeable deposits forming the present watersheds in "through" valleys. These conditions are described below, with examples.

Residual Soil and Weathered Rock

Deep weathering is prevalent in areas to the south of the regions covered as recently as 10 or 20 thousand years ago by the great ice-sheets of the Glacial Period in the Northern Hemisphere. There are two main reasons for this. South of the ice-sheets the weathered products of pre-glacial times have not been swept away by the ubiquitous erosion typical of ice. The blanket of impermeable boulder clay deposited by the ice-sheets is absent, and the rocks are therefore unprotected from the action of percolating rain-water. To a varying extent, according to the local conditions, weathered rock and superficial residual soil have been removed by such normal processes of erosion as soil-creep and rain-wash, and been finally carried away by streams and rivers. In hollows in which there is no stream this gravity action may be practically in abeyance, and the mantle of weathered rock may therefore be expected to be thick. This situation was present at Sheepstor, along a hollow leading out from the site of Burrator reservoir, near the margin of the Dartmoor granite north-east of Plymouth, in Devonshire. The bottom of the hollow lay below the proposed top-water level, and so a cut-off dam across it formed part of the scheme of construction. It was, however, not realised how deeply the granite underlying the hollow had been decomposed. Nor could it be known that a further difficulty would be encountered.

The granite, when excavated, was found to be soft and clay-like and also to be traversed at frequent intervals by highly inclined bands of quartz-rich rock up to 3 ft. in width. The quartzose bands (veins)

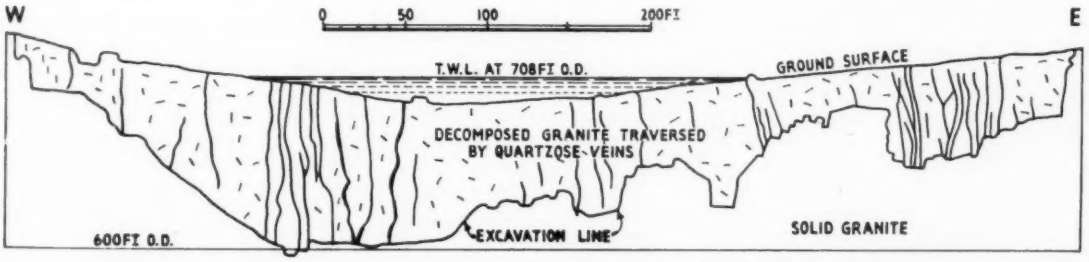


Fig. 11. An example of deeply weathered granite traversed by fractured and so permeable quartzose (greissen) veins. Sheepstor cut-off dam-trench, N.E. of Plymouth, England

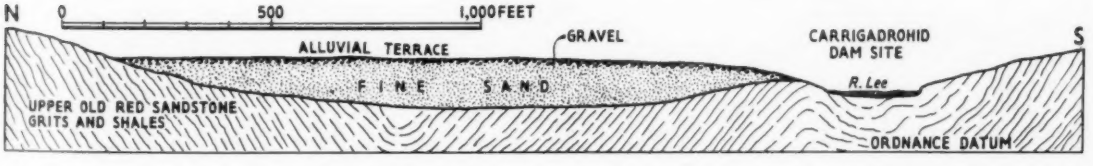


Fig. 12. Section across valley of River Lee, Co. Cork, Ireland, at site of Carrigadrohid dam. (By permission of Chief Engineer, Electricity Supply Board, Dublin)

Fig. 13. High-level alluvial terrace. The outwash fan from a glacier forms an adequate valley dam on the River Lee, Co. Cork, Ireland. Present river flows in a rock-bounded ravine at Carrigadrohid where a dam is being constructed. (Photo by Dr. Farrington)

though of impermeable rock were divided up by cross-fissures, so that a band seen sideways resembled a dry-stone dyke. At relatively little depth the clay-like granite was of adequate strength and sufficiently impervious considering the small head of water (17 ft.) for the foundations of the proposed earthen cut-off dam. But the quartzose bands disposed in a direction crossing the line of the cut-off, maintained their abundant cross-fractures to a much greater depth and constituted channels for leakage. So excavation had to be continued until these fractures and a copious supply of water coming from them ceased to occur (Fig. 11). At that time (about 1893) the technique of pressure grouting had not been developed, and would probably be used now for sealing fissured rock of such a nature.

The published descriptions of the rocks[11] have been in part interpreted for the writer by Mr. H. G. Dines of the Geological Survey, London. This interpretation is of particular interest, and the writer wishes to record his indebtedness for it. The clay-like nature of the granite was the result of the ordinary chemical action of rain-water which reduces the felspar of the granite to clay. The origin of the quartzose bands, geologically called greisen veins, is undoubtedly connected with a late stage in the crystallisation of the granite from the molten state. At this stage the granite now exposed near the present surface of denudation was solid and, owing to contraction on cooling, had developed a series of closely-set joint-planes. Hot water bearing silica and other substances in solution penetrated along the joints from some deeper-seated and less consolidated portion of the granite-mass, and converted the felspar in the granite adjacent to the fissures into quartz. This resulted in the formation of the quartzose bands. The recent deep weathering of

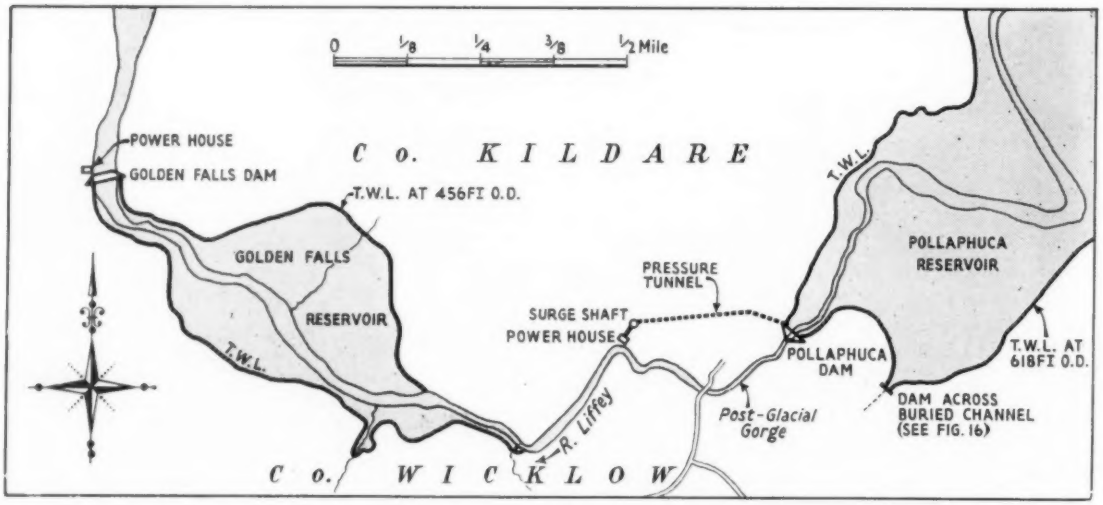


Fig. 14. Map showing Upper Liffey hydro-electric schemes, Ireland. (By permission of Chief Engineer, Electricity Supply Board, Dublin)

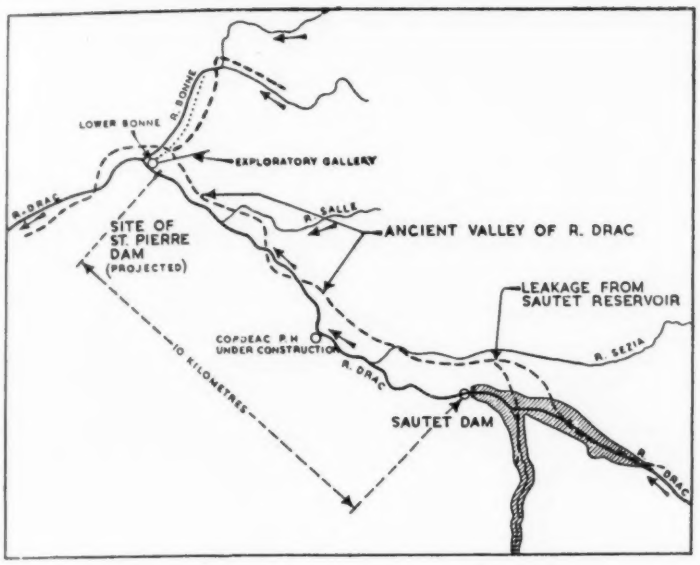


Fig. 15. Ancient and modern valleys of the River Drac, south of Grenoble, France; the pre-glacial course is shown in dotted lines

the granite, and alteration of the felspar ubiquitously to hydrous minerals composing clay, would cause swelling of the altered material and lead to the setting up of strains between the weathered granite and unaltered quartzose bands, with the result that the latter became abundantly fractured. In support of this explanation, it is noteworthy that at depth the fissures were filled with clay. At the level to which the excavation was taken the fissuring in the quartzose bands had disappeared, so that the bands "became one with the granite . . . although their course through the latter was plainly marked."[11]

Drift-filled Valleys

It is a common feature of rivers that they are out-of-centre with the valleys along which they flow. This is usually the result of the deposition of superficial deposits covering the deeper parts of the original rock-bounded valley. The present river-bed therefore is often at a higher level than the bottom of the rock-valley, and is cutting its course entirely in rock along one side or the other of the original rock-hollow. If a dam is to be constructed across the river, the possibility of leakage from the reservoir through the infilling materials, if these are permeable, has to be considered. Two types of materials are involved; river or lake alluvium, forming flat-topped terraces of sand, silt and gravel, and, in glaciated regions, moraine laid down by the retreating ice. If the infilling is clay, such as glacially-formed boulder clay devoid of intercalations of sand or gravel, probably no danger will exist. But it must not be forgotten that deposits of gravel or sand are encountered in some areas below boulder clay. In fact, it is not safe to rely on any superficial deposit until its composition down to rock-head has been determined, and this can only be done by sinking trial pits or bores at as many places as the circumstances may require.

Two instances of many which might be cited from various parts of the world are described below, one concerning alluvium and the other moraine. Both are from Ireland where, in Dublin, the details were supplied most generously to the writer by Mr. J. Macdonald, Chief Engineer of the Electricity Supply Board, and by Mr. O'Brien, Director of the Geological Survey, and Dr. Farrington of the Royal Irish Academy.

The River Lee flows eastwards to reach the sea at Cork, the course of the valley having been determined by the dominant W.-E. geological "grain" of that region. The rock consists of grits and cleaved shales, or slates, of Old Red Sandstone Age. These strata, together with overlying Carboniferous Limestone, were thrown into steep-sided folds by the Hercynian mountain-building movements. In consequence, the beds "strike" west and east and are inclined at high angles. These planes of weakness determined the course of the original river, which eroded the valley prior to the Ice Age. At that time the land stood higher relatively to the sea than at the present day, and the lower part of the rock-bounded valley at and below Cork now lies well below present sea-level. The valley-floor is covered with thick alluvium at many places. Two reservoirs are to be formed by constructing two dams, one of which, at Carrigadrohid, about 10 miles west of Cork, illustrates the problem of leakage in the case of alluvium (Fig. 12). The dam is being built across a rock-gorge cut by the present river along one side of the alluvium-filled valley (Fig. 13). Bores put down through the alluvium to rock-head have shown that the bottom of the old buried rock-valley lies about 20 ft. lower than the bed of the river, to which has to be added the height of the dam (60 ft.). The possibility of leakage from the reservoir through the alluvium was thus an imminent one. The bores showed, however, that below superficial coarse alluvium, there was very fine sand or silt of low permeability. This fact, coupled with the wide extent of the alluvial ter-

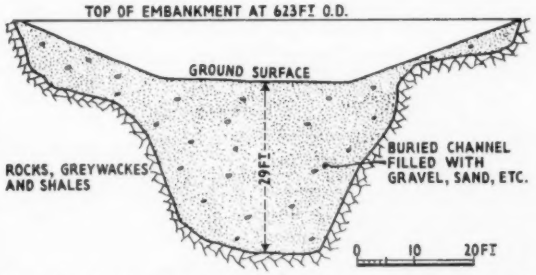


Fig. 16. Section across buried channel along line of cut-off dam, on south-east margin of Pollaphuca reservoir, Co. Wicklow. (By permission of Chief Engineer, Electricity Supply Board, Dublin)

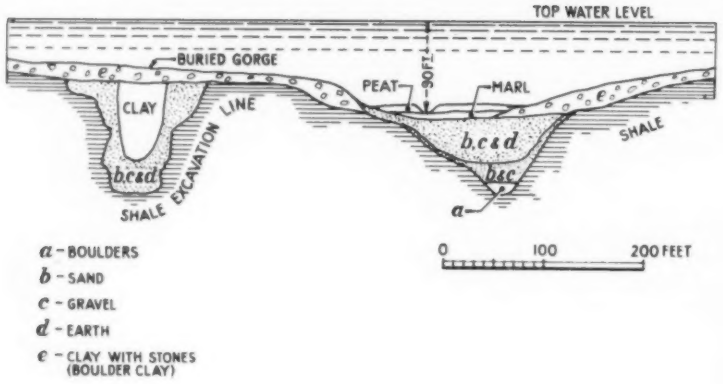


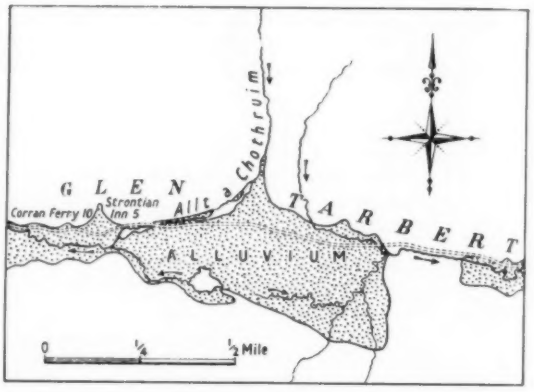
Fig. 17 (left). Portion of dam trench, Turner's Embankment, Yarrow reservoir, Rivington, N.N.E. of Wigan, Lancashire. (After H. Lapworth, Trans. Assoc. Water Eng. 16 (1911))

Fig. 18 (below). A corrom ("balance") formed by alluvium at watershed of a "Through" valley, Glen Tarbert, west of Loch Linnhe, 14 miles S.W. of Fort William, Western Highlands of Scotland. (Crown copyright reserved—Geological Survey, 19, Grange Terrace, Edinburgh)

race along the valley, led the engineers to conclude that the chance of any appreciable leakage was remote, as the length of the alluvial terrace along the valley averaged 1,500 ft.

A similar situation was encountered in the United States, although there were two vital differences, and on this account the circumstances may be worth recalling. In the case of the Cedar Creek reservoir, Seattle, Washington, the spread of alluvial material downstream from the dam consisted of permeable gravels forming part of a vast outwash fan at the front of a valley glacier during its retreat. Contrary to what is customary, the glacier had been in retreat down-valley, with its front facing up-valley, and along the down-valley side of the outwash fan, next to the ice, a veneer of boulder clay had been deposited. The clay acted as a relatively impervious though weak barrier which held up water seeping down-valley through the alluvial terrace from the reservoir. On the raising of the level in the reservoir, the water therefore became piled up in the alluvium against the boulder clay, and the latter eventually gave way, in 1918, with disastrous results.[12] The height of the concrete dam was 80 ft., and the distance from the dam to the point where the burst occurred was 6,000 ft. away.

Moraine often forms an infilling of pre-glacial rock-bounded valleys in hilly or mountainous areas. Its degree of permeability varies widely in different places. The matrix in which the stones and boulders are embedded ranges from almost impermeable fine silt to permeable coarse-textured sand. A case where safety was assured is along the upper reaches of the Liffey on the borders of Kildare and Wicklow, south of Dublin. There the post-glacial river follows a wide hollow which was formerly the site of an ice-dammed lake and is covered with bedded sands and gravels. Downstream from the hollow the river has cut a gorge in the rock-bounded side of the old valley (Fig. 14). A dam was constructed across the head of the gorge, at Pollaphuca, and the hollow upstream utilised for the reservoir. Farther downstream again a second dam, at Golden Falls, was built. It was known that these works were situated on the southern side of an extensive pre-glacial valley, the central and deepest parts of which were expected to lie well to the north of the present river. Bores were put down to ascertain the chances of leakage through the deposits filling the buried valley. These proved that the centre of the valley extended east and west at a distance of half a



mile north from the present river and at a depth of 132 ft. below the surface level at the higher of the two dam-sites. No cut-off dam was required, for the width of the infilling of morainic "drift" between both the reservoirs and the old valley-floor provided an adequate safeguard against any leakage danger.

The subject of buried valleys cannot be dismissed without a reference to those of the South of France, along the Rhone and the headwaters of one of its tributaries—the Drac south of Grenoble—and to the unexpected leakage along the buried valley of the Drac from the Sautet reservoir (Fig. 15). The diversions to new channels took place after the retreat of the ice, as in the case of the River Liffey, the old channels becoming filled with fluvio-glacial alluvium. Recalling the immense amount of exploration work carried out in the narrow limestone gorge where the Sautet Dam, 414 ft. high, was built, it seems indeed an unkind chance that leakage from the reservoir should have been so excessive—53 million gallons per day, especially in view of the length, almost a mile, of the old valley concerned. In contrast, estimates of leakage recently computed farther down the Drac at the site of the proposed St. Pierre Dam amount to only 4·5 million gallons a day. The latter investigation was carried out by means of an exploratory tunnel driven from the side of the present gorge through the deposits filling the ancient channel.[13]

Narrow Buried River-channels

Two instances of "buried channels" cut by glacier-fed streams during the retreat of the ice and filled

with permeable materials illustrate interesting differences. One of these occurs at the margin of the Pollaphuca Reservoir referred to above, and was apparent on the ground as a slight depression (Fig. 16). The depression was found on excavation to mark only the top of a steep-sided channel crossing a rock-bridge composed of Ordovician greywackes and shales. The channel had been eroded by overflow waters of the ice-dammed lake already mentioned, its depth below the bottom of the superficial hollow being 29 ft. It was filled with fluvioglacial deposits of sand and gravel which had to be dug out and a concrete cut-off dam constructed.

The second example is from Lancashire, along the Yarrow Valley N.N.E. of Wigan. There, adjacent to the river, an unsuspected buried gorge was discovered during investigations for a dam (Fig. 17). In this case there was no surface indication such as a hollow above the buried gorge, and indeed the surface deposit consisted of boulder clay which might well have been assumed to extend down to rock-head. The rock-lined bottom of the buried gorge lay at a great depth (110 ft.) beneath the base of the sheet of boulder clay, the gorge being filled in part with permeable gravel and sand. The river-bed itself was underlain by an almost equally deep rock channel filled with sand, gravel and earth, with a layer of boulders at the base. Both channels had to be completely excavated to rock for the foundations of the earth dam known as Turner's Embankment.

"Through" valleys are of ancient date, belonging to a time when a system of drainage differing from the present one dominated the topography. They are truncated at one or both ends by later, more deeply eroded valleys. In mountain regions they are especially common and often possess two rivers flowing in opposite directions from a low watershed. The watershed may be rock but more often consists of a moraine deposit. Sometimes, too, an alluvial cone or subaerial delta has been deposited across a through valley by a stream or streams flowing down the valley side. In this case the cone is termed a corrom, a Gaelic word applied in this sense by Sir Edward Bailey in the Scottish Highlands and meaning a "balance." The term is appropriate in that it is a matter of chance whether the water of the tributary stream passes from the corrom down the through valley in one direction or the other (Fig. 18). Should either river in a through valley be dammed, with the reservoir extending back to the watershed, it will be necessary to ascertain whether the watershed is composed of permeable materials or not. If it is a moraine, or a corrom, a cut-off dam will probably be required.

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Iraq Flood Scheme

The final stage of the Habbaniyah flood scheme will be reached this year with the completion of the Ramadi barrage spanning the river Euphrates. The barrage is 209 m. long and includes a navigation lock, a fish ladder and 24 gate openings. All the water-control gates, operating machinery and structures have been designed, manufactured and tested by Ransomes and Rapier Limited at their works in Ipswich and are now being erected under the supervision of the Company's engineers.

The 24 gates are each of 6 m. span and 8 m. deep, while the lock gates are 6 m. span by 8·5 m. deep; all are electrically operated. There is a double-leaf lift bridge spanning the navigation lock.

In addition to the Ramadi barrage, the Habbaniyah scheme includes three main canal regulators, one at Warrar with 24 gates (6 m. span and 7·5 m. deep), one at Mujarah with eight gates (6 m. span and 6·5 m. deep), and one at Dhibban with five gates (6 m. span and 4·7 m. deep). All these gates, structures and operating machinery were also designed and manufactured at Ipswich. The Habbaniyah flood scheme not only controls dangerous flood waters but ensures the irrigation for agriculture of large areas of what was previously desert land.

Hydraulic Turbines and Accessories. Bulletin 1001, recently published by Baldwin-Lima-Hamilton Corp., Philadelphia, Pa., U.S.A., illustrates the company's hydraulic turbine research facilities and describes the different types of hydraulic turbines and associated equipment which have been built for various hydro-electric projects. This 22-page booklet also contains approximate equations which can be used as a general guide in the preliminary selection of turbine speeds and sizes for application to given conditions of head and horsepower, or turbine discharge. It is handsomely produced and illustrated.

From page 342

M.I.C.E., and Mr. T. A. L. Paton, M.I.C.E., of Sir Alexander Gibb and Partners, for whom the models were carried out, for permission to describe the tests and for the photographs from which the figures were prepared, and also to Professor C. M. White, PH.D., D.SC., of the Imperial College of Science and Technology, London, under whose direction the latter two models were operated.

The paper was originally read before the Association of London Graduates and Students of the Institution of Civil Engineers, by whose permission it is here published.

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Fittings for Overhead H.T. Transmission Lines

Notes are given on some of the points which have to be considered in the manufacture of the auxiliary fittings used for transmission lines if safe and continuous service is to be assured

THE art of transmitting electrical energy has made progress in virtue of the higher and higher voltages which it has been possible to introduce and also because of the larger conductor diameters and greater lengths of spans which can now be used. This progress continues. In transmission lines in Europe conductors ACSR of 35/40 mm. diameter are now being used with ultimate strengths of 18/20,000 kg. Spans of about 400 m. in length are not uncommon and in some cases reach 500 m.

The design and construction of these heavy-duty lines requires careful consideration and particular attention needs to be devoted to all the accessory equipment and fittings, such as joints, dead ends, yokes, spacers, vibration dampers and so on. Of equal importance are the accessory fittings required for the insulator strings, especially those under great strain.

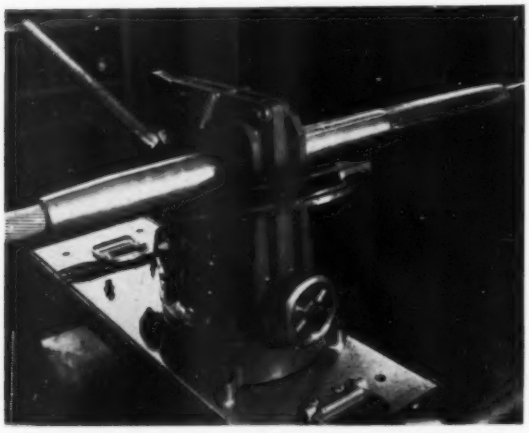


Fig. 1. Hexagonal compression system dead-end clamp and joint, suitable for 34·6 mm. conductor

Fig. 2. U-bolted dead-end clamp in forged steel suitable for conductors up to 32 mm. dia.

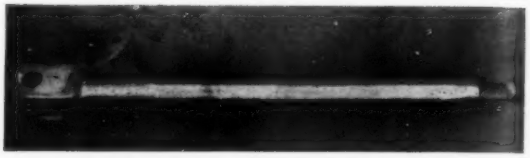


Fig. 3. Dead-end clamp and joint hexagonally compressed

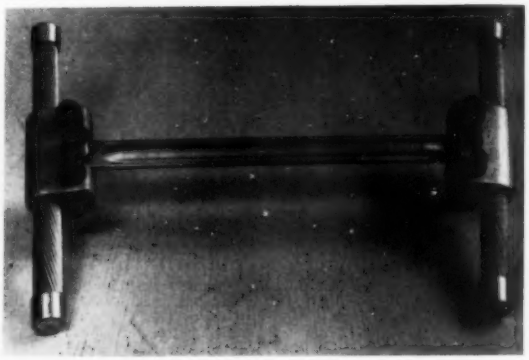


Fig. 4. Stainless steel spring spacers for twin conductors

Accessory fittings, already important enough in the past, become of supreme importance in the operation of large modern networks where failure of service would affect large communities and disorganise many industrial activities. The cost of these fittings is small in comparison with the total cost of the transmission line itself, as an expense of 2 or 3 per cent. is inconsiderable in relation to the important duty they perform in securing reliability of service.

The production of transmission-line accessories is limited to a few specialised manufacturers who have generally had a very extensive experience. Among these the Società Elettro-Morsetterie Volpato, Milan, Italy, is more or less typical, having concentrated its attention on the design and manufacture of transmission-line accessories for 30 years. As they have been under the necessity of adapting their fittings to the onerous duty of meeting the needs of lines traversing the Alps, their methods have a general interest.

The most important accessories are as follows: *(a)* Compression joints and dead ends; *(b)* Suspension clamps; *(c)* Vibration dampers; *(d)* Protection for insulators and conductors (guard rings and arcing horns; and *(e)* Spacers for twin-conductor lines.

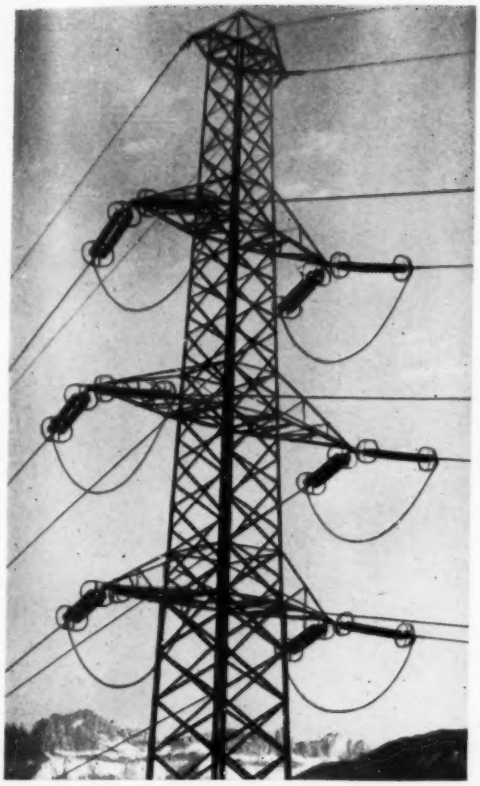


Fig. 5 (above). 220 kV 26·9 mm. ACSR high-altitude transmission line

Fig. 6. Anti-vibration trunnion-type suspension clamp in forged steel or forged aluminium alloy

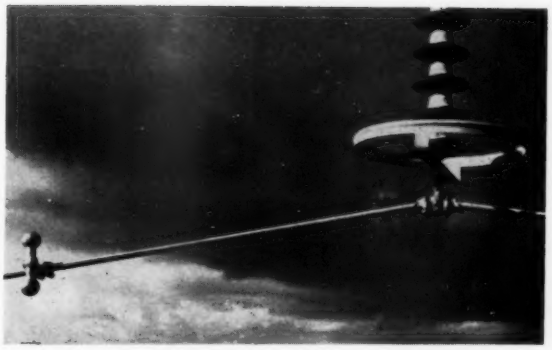


Fig. 7. Dumbell torsional dampers on a 220 kV line having 29·3 mm. ACSR conductors

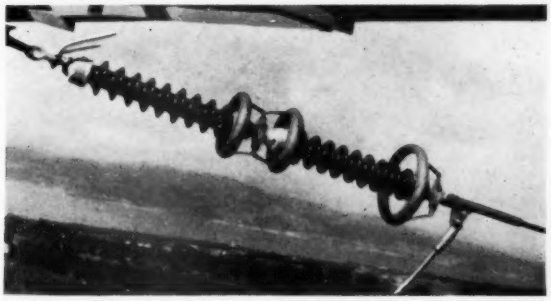


Fig. 8. A 150 kV 22·4 mm. ACSR line equipped with "Langstab" insulators

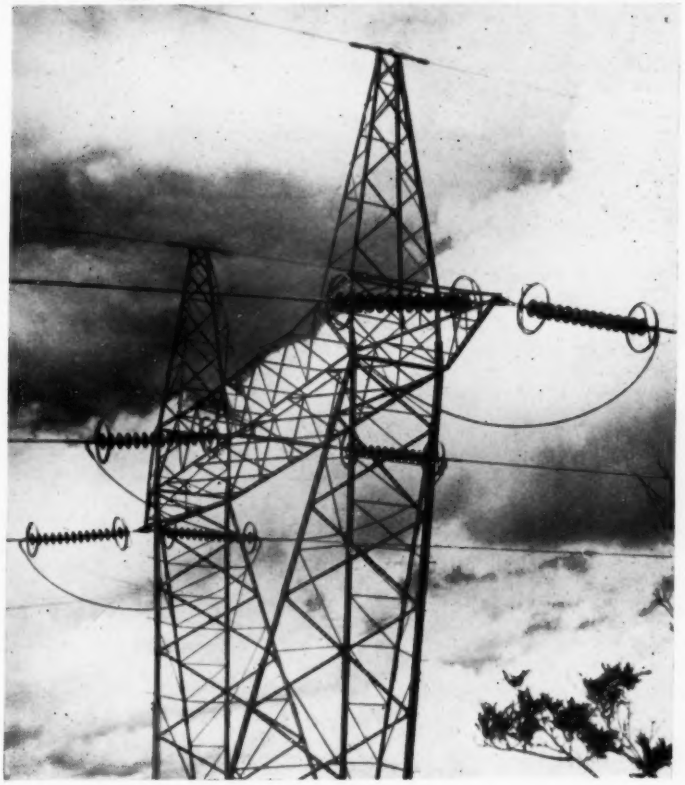


Fig. 9 (right). Illustrating hexagonal compression clamps in use on a 161 kV 25 mm. ACSR line in Brazil

All these accessories require accurate design, manufacture and thorough testing during the manufacturing process.

Compression joints and dead ends. In making compression joints and dead ending ACSR conductors there are two types of fittings available, the more common round type, suitable for use with two aluminium layers and the hexagonal fittings (Figs. 1 and 3) with three or more aluminium layers. For these larger conductor sizes, mostly of aluminium, it is claimed that the hexagonal compression fitting has the advantage of keeping the round conductor in proper shape after compression and does not deform the three aluminium layers. Another advantage claimed for hexagonal compression lies in the fact that the pressure is exerted in six directions instead of only two as in the case of the round type. Moreover with hexagonal compression, the effort of the compressor itself is 40 per cent. less than that required by round compression fittings.

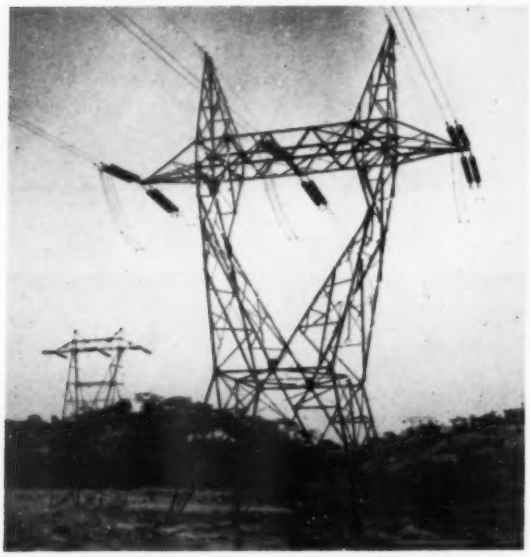


Fig. 10. Line connecting Haut Katanga, Belgian Congo, to Northern Rhodesia. This line is believed to be the longest in Africa, 510 km., the twin conductors carrying 220 kV

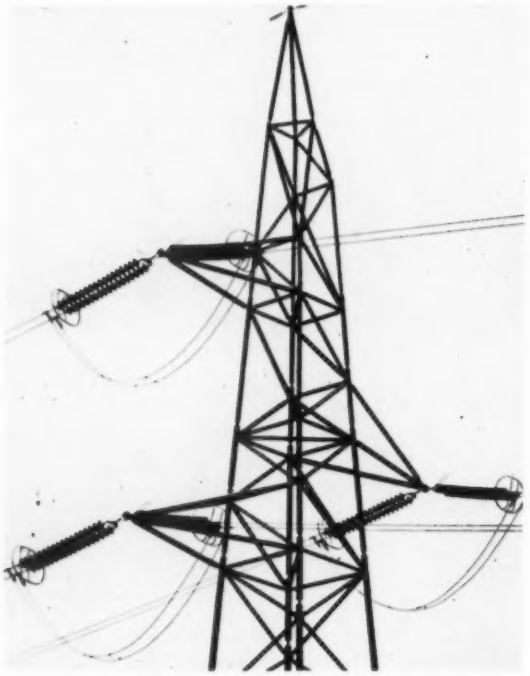


Fig. 11. Terni-Apuania line, 230 km. in length and 220 kV. The towers are constructed of vibrated concrete rods fitted with dissembling pieces

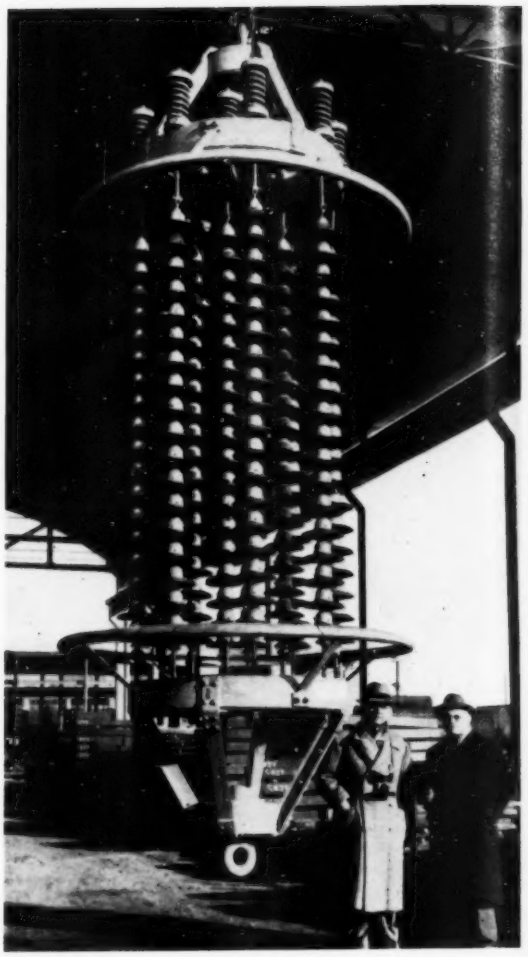


Fig. 12. View of the 12-string strain equipment for the 220 kV Messina crossing, tested at 75,000 kg.

For customers who do not wish to use compression dead-end clamps, in which the conductors are cut, the U-bolt type of clamp may be supplied. Here they have the choice of two to seven U-bolt clamps further increasing the diameter of the conductor (Fig. 2). These clamps are manufactured in malleable iron, forged steel, or forged aluminium alloy (non-magnetic) Experience has demonstrated that the overall aluminium strands are not damaged by the use of these clamps.

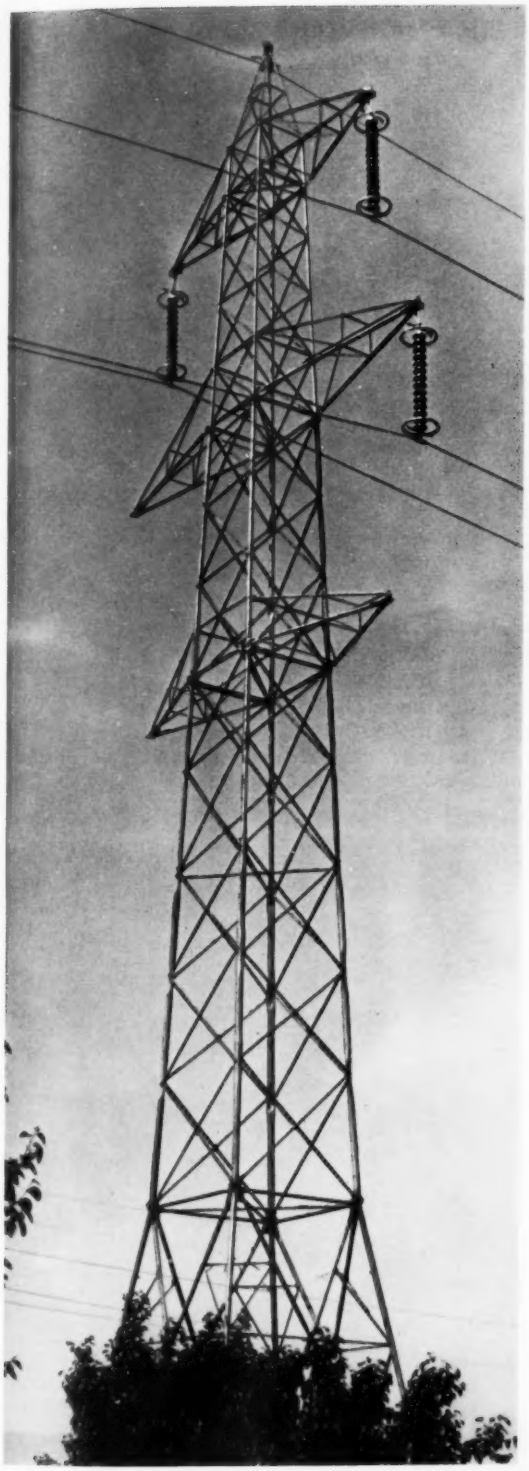


Fig. 13. One of the towers, constructed in tubing, for the 220 kV 26·9 ACSR, connecting Bolzano and Cislago

Suspension clamps. Suspension clamps are of equal importance, due to the problem raised by vibration, and several systems are in use to reduce vibratory effects. "Active" systems, such as the American Stockbridge and Canadian Dumbell (Fig. 7) are both of equal efficiency in acting against vibrations or reducing their intensity. There are also "passive" systems using armour rods for reinforcing conductors at their clamping points to reduce breakage from vibration. Trunnion suspension clamps, snubbed in all directions and made of malleable iron, forged steel and forged in non-magnetic light alloy, are also available. This type (Fig. 6) is very effective and may be used in most cases without armour rods or dampers.

Another important detail of high-tension transmission-line construction is the protection provided by grading shields (guard rings) and arcing horns. Grading shields must be designed to provide proper distribution of potential in the insulator strings and protect insulators and conductors from flash-over (Figs. 7 and 8). Normal arcing horns, or the Swedish type, only protect the insulators and line from flash-over.

Spacers. A difficult problem has arisen in connection with twin conductors or multiple lines now being constructed for use in Sweden, Italy, Great Britain, Canada, Russia and Germany. Spacers must be strong and well snubbed to avoid conductor lapping (pitch from 380 to 450 mm.) without damage (Fig. 4). These accessories are very important and the company were the first constructors in Italy of these fittings. This experience may suggest better solutions to the problem, although with the use of stainless steel (8/18) springs they have so far been perfectly satisfactory.

Worthy of mention is the 220 kV line of the Società Terni in Rome, running from Terni to Genoa, completely equipped with spacers as shown in Fig. 4. The 510 km. line operating at 220 kV running from the Belgian Congo to Northern Rhodesia (Le Marinel-Kitwe) is also equipped with this type of spacer. This line was constructed jointly by the Union Minière du Haut Katanga in Bruxelles and the Anglo-American Corporation of South Africa, Limited, of Johannesburg (Fig. 10).

Attention may also be called to the Messina crossing which will be completed during the present year. It contains one span 3,650 m. in length operating at 220 kV, constituting the largest span in the world. The towers are 224 m. in height and were constructed by the Società Anonima Elettrificazione (S.A.E.) of Milan. These towers will be furnished with a lift. At present four 27·8 mm. steel conductors (with aluminium filler) and having an ultimate tensile strength of 60,000 kg. are being used. The special suspension equipment for this crossing, which has eight insulator strings guaranteed for 50,000 kg and exceptional strain strings with 12 insulator strings guaranteed for 75,000 kg. was designed and is under construction by the Società Elettro Morsetterie Volpato, Milan, Fig. 12.

These suspension and strain strings are provided with compensation springs which have been separately tested and have been easily able to meet their respective guarantee strengths. The design and construction of this important crossing is a fine tribute to Italian technique and courage. Furthermore, it has been financed by private means supplied, in part, by Italian electric utility companies with assistance from the Società Generale Elettrica della Sicilia (S.G.E.S.).

New Powerful Tractor Model

Fig. 1. D9X equipped with self-loading No. 90 scraper, removing overburden

The Caterpillar Tractor Company of Peoria, Illinois, U.S.A., are now manufacturing what is claimed to be the largest and most powerful crawler-type tractor produced. This, the D9X., weighs 56,000 lb. and is powered by a six cylinder diesel engine, 6¼ in. bore 8 in. stroke having a total piston displacement of 1,473 cu. in. Equipped with a turbocharger, this overhead valve engine develops 286 h.p. at the flywheel at the governed full-load speed of 1,200 revs. per min. The engine is started by an independent two-cylinder petrol engine.

Two transmissions are available, direct or torque converter. The latter comprises a three-stage, 5 : 1 torque multiplication unit using diesel fuel for the hydraulic fluid which is cooled by means of a water-type heat exchanger mounted on the right-hand side of the engine. The flywheel clutch used with the torque converter is a 19 in. single plate, dry-type unit and three forward speeds and two reverse are provided giving speeds up to 7·8 m.p.h. The direct-drive model has six forward and six reverse speeds ranging from 1·6 to 6·8 m.p.h. and, with this transmission, a drawbar pull figure of 60,860 lb. is claimed to be possible with adequate traction conditions.

A one-piece welded track roller frame is fitted, and this includes a closed oil-type-recoil spring housing and track-guiding guards at each end of the frame. The equaliser bar rests on moulded rubber pads on the seven-roller track frame. The standard track shoe is 24 in. wide and there are 43 shoes to each track. A total ground contact of 6,228 sq. in. is obtained as each track as a ground length of 129¾ in. The track is adjusted hydraulically. Also available are 27 and 30 in. shoes as optional equipment.

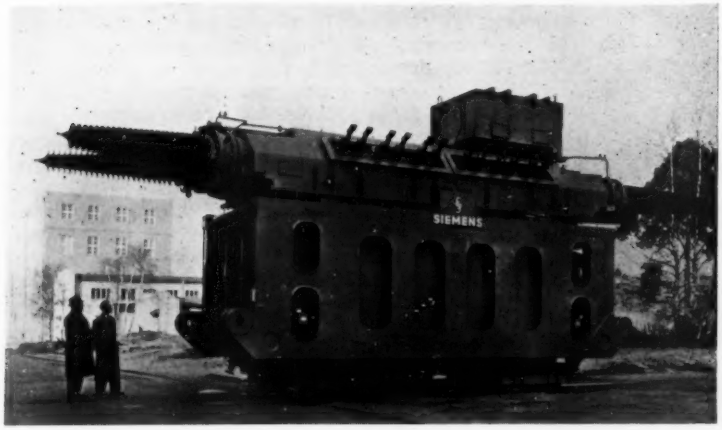
The general appearance of the D9 conforms to the other five models of Caterpillar crawlers. The length is 17 ft. 10 in., the width 9 ft. 11 in., the height (excluding exhaust pipe and air cleaner) 8 ft. 9 in., while

Fig. 2. The D9X on a bulldozing operation, clearing a site

the ground clearance is quoted at 21 in. The conventional drive model weighs 56,200 lb. and the torque converter version 56,650 lb. The weight per drawbar h.p. is specified as 235 lb.

World's Largest Transformer

What is claimed to be the world's largest transformer has been built for the Rheinische-Westfalische Elektrizitäteswerke by Siemens-Schuckertwerke A.G.



The Siemens-Schuckert 200,000 kVA 10·5/245 kV transformer built for the Rheinische-Westfalische Elektrizitätswerke

at their transformer works in Nürnberg. It is rated at 200,000 kVA, 10·5 kV/245 kV, and is of the transportable type with built-in cooling radiators. Overall it is nearly 50 ft. long and weighs 208 tons without the oil filling, which adds 30 tons to this total. For its transport from the works to the power station in the completely assembled condition, this transformer was suspended between two special 9-axled railwav trucks.

Helicopters Used on Hydro Work

Helicopters loaned by the Royal Australian Navy have recently been used to assist in construction work on a new hydro-electric project in Tasmania. Surveyors were first dropped on the top of Mount Wedge, in the rugged south-west section of Tasmania, to erect a beacon. They were returned to the base at Butler's Gorge a few hours later, after completing an operation which would otherwise have taken four men, with several packhorses, a month. The helicopters also flew geologists to many sites on the King, Franklin and Gordon rivers, making in a day visits which would otherwise have involved months of track-cutting. Civil engineers were also taken to inspect possible sites for dams on the Jane, Franklin and Gordon rivers and along the Pieman and its tributaries. On some occasions, the engineers were put down by winch or rope ladder, and on others the helicopter landed on islands in the rivers. Levels were obtained all along the Gordon river—a process almost impossible on foot because of the mountainous country and almost impenetrable scrub jungle.

Other feats of the helicopters, which were Bristol Sycamores, were the delivery of two tons of building materials to Lake Mackenzie, an isolated spot which could otherwise have been reached only by packhorses. The helicopters were also used as "aerial cranes" on the project, manoeuvring heavy concrete components into place 4,000 ft. above sea level, and electrical engineers were enabled to inspect transmission lines and a tower damaged by lightning on the previous night.

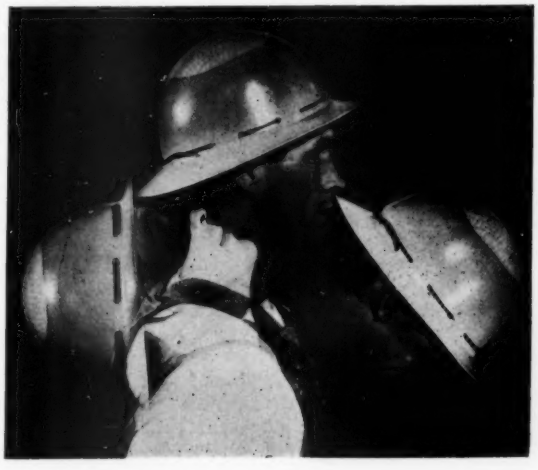
Later, when flying personnel and equipment from Great Lake, at an altitude of 4,000 ft., to Lake McKenzie, 15 miles away, where a river-gauging station was being erected, the Sycamores showed that they could handle in one day an operation which would have taken several weeks by packhorse. They also proved their ability to lift the 6½ cwt. drain-pipes.

Trips were made over virtually uncharted territory; carrying two or three passengers on each flight, the helicopter enabled geologists to obtain barometric levels and examine rock formations along the river gorges—a process impossible on foot. Parties were also taken from camp to camp, supplies delivered and specimens collected.

On another occasion civil engineers and geologists were taken on tours of inspection over the extreme south-west of Tasmania. It was shown that, with correct equipment, accurate contour heights could be plotted and barometric levels obtained from the air, while preliminary examination of dam sites could also be made from such landing points as gravel banks in rivers.

New Safety Helmet

The "Skullgard" safety helmet, illustrated in the accompanying photograph, is a product of the Mine Safety Appliances Company, Pittsburgh, Pa., U.S.A., and is moulded under high pressure from a single piece of hard, smooth, laminated plastic. The shape,



rounded contours, and strength of the helmet are designed to provide effective deflection of falling or flying objects and offer protection against bump-hazards for men working in tunnels, excavations and other close quarters where falls of material are likely to take place. It is claimed to offer extra protection in what have been described as the danger zones—the front, top, and back areas of the head. As will be evident, the new Skullgard covers these areas and incorporates a special reinforcement against impact.

New Portable Compressors

Ingersoll-Rand have now extended their range of portable compressors by the introduction of two new models—the two-tool TP. 110 and the four-tool TPG. 210. These units are now in full production at their Manchester works.

Fig. 1. TP. 110 model Ingersoll-Rand portable compressor

In both machines the engine and compressor are unit constructed to ensure positive alignment, the drive between them being taken by the well-proved, manually-operated, Borg and Beck over-centre segmental disc clutch. Quick and easy replacement of the linings is effected without disturbing either the engine or compressor.

The compressor is a two-stage machine (type 40) giving pressures up to 100 lb. per sq. in. with, it is claimed, 15 per cent. more efficiency than a single-stage machine. Other features are air-cooling (which eliminates freezing hazards), channel-valves of high efficiency, all-metal free air unloaders, and twin low-pressure cylinders for better cooling and balance.

In the TP. 110 the alternative of either the Gardner 3LW or the Ford 954E engine is available, the larger TPG. 210 being powered by the Gardner 5LW, all of which have a good reputation for reliability and low maintenance costs.

Easily detachable bodywork of similar design has been incorporated in both units. This can be quickly detached without disturbing either the engine or compressor, thus providing easy access for maintenance. On both models, non-detachable hinged side doors are provided, together with a lifting bale which is accessible for single hook suspension through a hinged door in the canopy.

The Model TP. 110 is available on any of four alternative mountings to meet every requirement, whereas the Model TPG. 210 is on a four wheeled running gear incorporating Ackerman steering with parking brake only. Alternatively, both models can be supplied less running gear for truck mounting. The smaller model has a capacity of 110 cu. ft. of free air per min. at 100 lb. per sq. in. pressure while the capacity of the larger is 210 cu. ft. per min., the respective horsepowers of the engines being 26 and 49. The overall length of the TP. 110 is 13 ft., the width over the mudguards 4 ft. 11 in. and the height 5 ft. 3 in.

Fig. 2. TPG. 210 model portable compressor

For the larger machine (type TPG. 210) these dimensions are respectively 15 ft. 3 in., 5 ft. 3 in. and 6 ft. 4 in. The weight of the TP. 110, with electric starting, is 3,760 lb., and that of the TPG. 210 is 5,710 lb.

Kitimat-Kemano Carrier System

The General Electric Co. Ltd. of England has supplied and installed a complete power-line carrier communication system for the Kitimat-Kemano project in British Columbia of the Aluminum Company of Canada. The normal line voltage is 300 kV and this is the first carrier system to be superimposed on such a high voltage in North America.

The generating station at Kemano is separated from the aluminium smelting plant at Kitimat, which it supplies, by 50 miles of mountainous country which is impassable by road. Further, at the time of installation there was no telephone connection between the two sites, the only means of communication being a V.H.F. radio link which necessitated maintaining a repeater station in extremely difficult terrain.

The new carrier equipment is designed to operate on an inter feeder basis, the signals being transmitted between one phase of one feeder and the corresponding phase of the other feeder. The wave traps (Fig. 1) are rated for 1,600 A steady line current. In addition to providing the usual speech and signalling facilities the system also provides unidirectional transfer tripping facilities, so that if a fault occurs anywhere in the

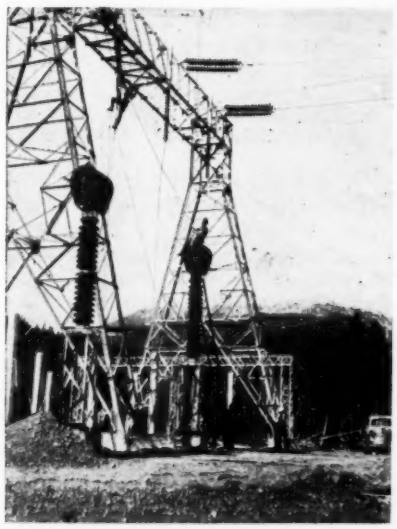


Fig. 1. G.E.C. power-line carrier-coupling equipment at Kitimat. The two wavetraps can be seen in the foreground

overhead lines the feeder breaker at Kemano is tripped.

The two sites are linked by three duplex telephone channels, one of which provides a direct connection between the two control desks for the control engineers. The remaining two channels work between the telephone exchanges at the two stations, and provide for fully automatic communication between the subscribers thereon. A telemetering channel also operates from Kitimat back to Kemano to indicate the line voltage received at Kitimat.

Changeover arrangements. All common equipment is fully duplicated and in the event of a fault occurring the changeover from normal to stand-by equipment is completely automatic. The power-line carrier

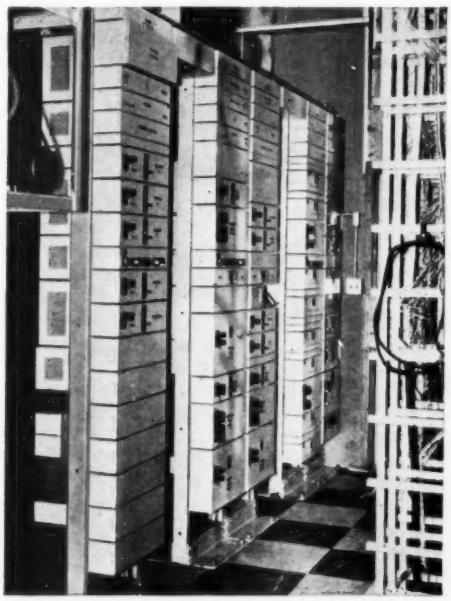


Fig. 2. G.E.C. power-line carrier equipment installed in the telephone exchange at Kitimat, adjacent to the control room

equipment (G.E.C. type "N") is a multi-circuit apparatus which is readily extensible to an ultimate capacity of five circuits. It is also provided with additional automatic gain control facilities to maintain the level of the circuits at their nominal value even during the unusually severe weather conditions which are experienced.

A.C. supply is obtained from a four-machine generator set, the object of which is to maintain a "no break" power supply to the power line carrier equipment in the event of a failure in the main supply. Under normal conditions the local a.c. power supply drives a 3-phase induction motor coupled to a single phase alternator by means of a flywheel. In the event of a supply failure, a stand-by d.c. motor is energised from the station storage battery, and drives a single phase alternator. When a changeover takes place the flywheel on the main set maintains the output from the main alternator until the stand-by machine has run up to speed.

Speech and protection. Each communication channel is 4 kc. per sec. wide, and consists of a speech channel from 300 to 2,700 cycles per sec. and a telephone signalling channel of 3,060 cycles per sec.

Abstracts from the World Technical Press

Hirakud Dam Project

This special issue of the undermentioned journal is entirely devoted to the Hirakud dam project and contains the following articles: Mahanadi valley development, by M. S. Thirumale Iyengar; The main dam and the dykes, by A. R. Chellani; Engineering geology of the project, by A. Acharya and B. Ramchandran; Foundation treatment, by R. C. Rao; The Power System, by N. Dharmarajan; The Canal System, by K. Padmanabha Pillai and K. C. Thomas; Hirakud reservoir and its problems, by R. P. Verma; Field laboratory, by R. C. Hoon; Camps and Buildings, by A. K. Pal; Hirakud dam project organisation, by S. Raghavachari; A good record (Editorial). (*Indian Journal of Power and River Valley Development*, Vol. IV, No. 10, 84 pp., many ff.)

Feather River Project

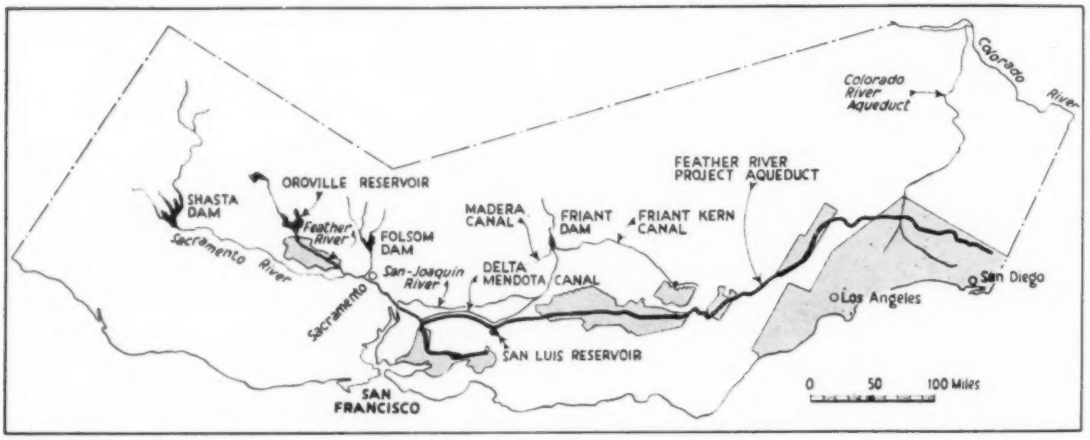
After three years study, California's Division of Water Resources has declared the Feather river project to be feasible. This is one of the most far-seeing water developments ever conceived, involving the construction of the world's biggest concrete dam, 20 ft. higher than Hoover dam, and more massive by 3·5 million cu. yards of concrete than Grand Coulée. The report just published outlines the three major features of the project:—two dams and an aqueduct. The Oroville dam, a gravity structure 730 ft. high requiring 14 million cu. yards of concrete, would block the Feather river, and have a power plant with an installed capacity of 440,000 kW; additional power would, however, have to be purchased to operate the pumping plant on the aqueduct. Assuming that construction work to start next year, completion of this dam is scheduled for 1963. The water released from Oroville dam would flow down the Feather and Sacramento channels to the Sacramento-San Joaquin river delta area, as already does the water from Shasta dam Pumping plants would then lift it to a total elevation of 3,353 ft. The total length of the conduit from the delta area to a spillway tributary to Barrett dam in San Diego County would be about 585 miles; included are two tunnels totalling 10·5 miles in length to take water through the Techachapi Mountains. The aqueduct is programmed for increment construction with first water delivery to San Diego County in 1976. A number of fore-bay and after-bay reservoirs are planned at the pumping plants, the biggest of them, with a capacity of 2·1 million acre-ft., would be created in Merced County by the San Luis dam, a 68 million cu. yard earthfill structure with a maximum height of 310 ft. By using surplus winter flows in the delta region, water from San Luis reservoir could be released to San Joaquin valley area by 1959. (*Engineering News-Record*, Vol. 154, No. 10, March 10, 1955, p. 21/22, 1 map.)

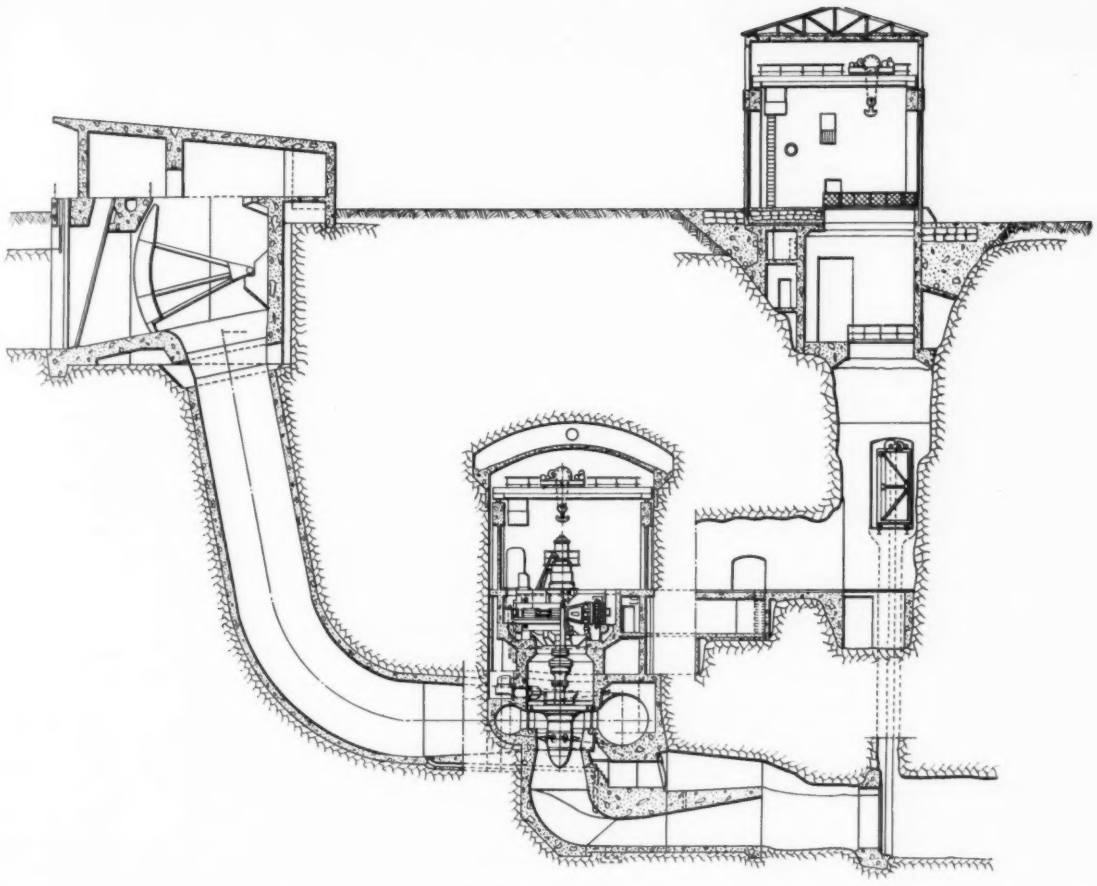
Influence of Generator Design on Dependability

This paper was read at a meeting of the Austrian Institute of Electrical Engineers, held in Vienna, and devoted to safety measures in hydro-electric installations. The author first approaches this subject from the viewpoint of the generator designer and shows how reliability in service can be improved by accurately calculating additional losses, and applying the results to improvements in design. This, combined with first-class workmanship, will, from the outset, eliminate some of the causes of possible failures. Many practical examples are mentioned, together with interesting details of design and actual workshop experience. Under the heading "Impulse Excitation" the second part of the paper gives an easily comprehensible insight into the behaviour of a generator with regard to system stability and the transient state after a short-circuit in the line. (Dipl. Ing. Dr. Techn. Karl Widdmann, *Elin Journal*, special edition in English of *Elin Zeitschrift*, March, 1955, p. 1, 12 pp., 19 ff.)

Dönje Power Station

A detailed description is given of the power station of the Dönje Kraft AB., a subsidiary of the well-known Swedish concern ASEA. The station is sited immediately downstream of lake Växsjön on an island in the middle of the river Ljusnan, and is flanked by a dam on either side. The western dam has three spillway passages and a log chute with electrically-operated gates; the gates of the intake are





operated hydraulically. The underground machine hall proper has been excavated to such a depth as to enable the two 26,500 h.p. Kaplan turbines to utilise to the full the 30·5 m. head available between lake Växsjön and lake Varpen. The tailrace tunnel discharging into the latter lake is 36·1 × 40·4 m. in cross-section; driven in the rock throughout its whole length of 2·9 miles. The draft tubes are provided at their outlet with gates which can be closed, when the turbines need overhauling, by means of an electric crane travelling on rails in a short gallery. The generators are designed for 27,500 kVA at 11,000 V and a speed of 187·5 r.p.m. Power from No. 1 generator is taken to the 70 kV outdoor switchyard through a transformer housed in a bomb-proof vault on the transformer floor of the power house. Following a decision to connect the Dönje plant with the 200 kV grid, the No. 2 generator is linked with a separate three-winding transformer mounted out of doors in a blast-proof concrete shelter. In addition to the 70 kV and 200 kV outdoor switchyards, the station comrises, above ground, an intake house, erection bay and control building. The erection bay and machine hall are connected by a shaft. (O. Sjöberg, *ASEA Journal*, Vol. 27, No. 11-12, November-December, 1954, p. 159, 19 pp., 25 ff.)

Bersimis Development

A description is given in broad outlines of this important project of the Quebec Hydro-Electric Commission. Bersimis will have an initial capacity of 600,000 h.p. and an ultimate capacity of twice this figure, the corresponding figures for the Kemano project being 420,000 and 2,240,000 h.p. respectively. The power house will be of the underground type and the generating equipment will consist of eight 150,000 h.p. units operating under a head of 875 ft. Compared to the 10 miles in length and 22 ft. in diam. of the Kemano tunnel, the Bersimis tunnel will be 7½ miles long and 31 ft. in diam., and while Kemano has a single rockfill dam 317 ft. high, there will be two rockfill dams at Bersimis, 200 and 230 ft. high. Bersimis is destined to take an important part in Quebec's power system as it is essentially a storage project needed to balance the large plant (ultimately 2,200,000 h.p.) at Beauharnois, on the St. Lawrence, which might loosely be considered as a run-of-the-river installation by comparison. The development is scheduled to deliver its first block of power by December, 1956. *(Engineering News-Record*, March 3, 1955, p. 28, 2 pp., 6 ff.)

High-Pressure Pipelines

This long article describes the notable contribution which Sulzer Brothers have made to the design and construction of high-pressure pipelines for hydraulic power purposes. It begins with a historical survey of the firm's activities, starting from 1841, at which time hydraulic pressure turbines were being put into use chiefly for driving textile machinery. By 1877 Sulzers

were manufacturing riveted pipelines up to 6 ft. in diameter and one of these, erected for the Kollbraun Spinning Mill, Switzerland, is still in service today. Riveted pipes held their own until the turn of the century but from then onwards water-gas welded and forged welded pipes began to be made. This was followed by oxy-acetylene welding in 1907 and shortly afterwards electric-arc welding was successfully developed, to be perfected by assiduous research and testing as the years went on, until it is now possible to weld thick-walled highly stressed and often complicated branch shapes in alloy steel. In this matter the article stresses the value of careful machining, heat-treatment and an adequate testing technique, all of which presupposes a wide range of experience to ensure a proper degree of safety .

The planning of the pressure pipeline is one of the most important aspects of high-head hydro-electric stations and the article proceeds to discuss this subject in relation to the terrain, access roads, the materials used, design of (a) surface-laid pipelines and (b) pressure-shaft linings, erection, and protection against rust. Some outstanding pipelines manufactured by the firm are then described in detail; among these may be mentioned the penstock for the Miéville station of the Salanfe S.A., Switzerland, which has a maximum service pressure of 2,300 lb. per sq. in. *Sulzer Technical Review* No. 4, 1954. 41 pp. 69 ff.

Durability of Concrete in Hydraulic Structures

The conditions affecting the durability, as well as the various causes of concrete deterioration in hydraulic structures, are discussed in detail, recommendations being made with a view to improving the quality. In dams and related civil engineering works, the prime requirements are stated to be efficient control of volume variations and the provision of a concrete that is impermeable. Though far from being satisfactorily concluded, permeability tests have shown that the cement content in many types of structure can be substantially reduced and yet give rise to an adequately impermeable concrete, especially for the inner parts of massive structures. Research alone can ensure a realistic approach to the determination of cement content in concrete mixes in which impermeability is the primary requirement. Further exhaustive investigations are therefore considered necessary, and should include the types and gradations of aggregates and cement, water/cement ratio, air entrainment, placing techniques, curing methods, surface shrinkage, and the many other factors involved. Progress in this field can only be achieved by constant and efficient co-ordination of research and practice on the one hand, and technique and economics on the other. (N. S. Govinda Rao and K. T. Sundara Raya Iyengar, *Irrigation and Power*, Vol. 12, No. 1, January, 1955, p. 90, 12 pp., 1 f.)

Heavy Electric Equipment in France

In this paper, read at the monthly meeting of the Société française des Electriciens on February 3, 1955, the author first reviews the great strides made in France during the last 25 to 30 years in the construction of heavy electric equipment, particularly generators and transformers, by the use of materials of better quality (magnetic steel plates, insulating materials, etc.), their more rational application, and improved design. The substitution of rolled and welded steel for cast steel has, for instance, resulted in spectacular reductions in the weight and size of alternators. Special stress is laid on improved insulation. Mica still remains the basic insulating medium in H.T. windings but synthetic resins are coming to the fore, and manufacturers can now avail themselves of new heat-resisting insulating materials. Hydrogen tends to replace air as a cooling agent, permitting, as it does, the transfer of a much larger amount of heat from the alternators while, at the same time, reducing ventilation losses. Thanks to the advance of electronics, regulation has substantially improved both in speed and reliability. The paper concludes with remarks on standardisation; standardisation of heavy equipment is considered to be a much more difficult proposition than is the case with small items of machinery or tools. In consideration of the small number of manufactured examples of each type the aim should be to reduce the number of types, particularly by bringing French standards into harmony with foreign and international standards. (Roland David, *Bulletin* de la Société française des Electriciens, series 7, Vol. V, No. 51, March, 1955, p. 127, 9 pp., 9 ff.)

Air-entraining Agents in Concrete

The various tests dealt with in this paper are a sequel to the investigations made at the Hirakud Research Station for the purpose of selecting an air-entraining agent for use in the construction of the concrete portion of the Hirakud Dam, and described in detail in the Station's report for 1952. Both Dresinate X and Vinsol Resin NVX had been examined in the 1952 tests; in most of the studies under review, the latter only was tested. The main conclusions of the report are as follows: With the type of crushed aggregate used at Hirakud, sand and water content of the mix can be reduced respectively by about 1 to 1½ per cent. and 8-10 lb. per cu. yard of concrete. The reduction in bond strength, about 35 lb. per sq. in. for each per cent. of air entrained, is not of a high order, and is compensated for by the increase resulting from the reduced water-cement ratio. The amount of the agent added remaining equal, the air-content in the concrete increases with the fineness of the sand. The maximum improvement in workability, brought about by the use of entrained air, is felt only when the sand is well graded. With the use of Vinsol NVX or Dresinate X, as entraining agent, vibration to the extent resorted to at the job is not likely to reduce the air-content unduly. As to expenditure, overall cost of concrete is not increased by the use of air-entraining agents; on the other hand, following the reduction in the aggregate used and the possible reduction in cement content of the mix, there is a reduction in the total cost which combines with the benefit resulting from the improved permeability of the mix. (Hirakud Research Station, *Irrigation & Power*, Vol. VI, No. 4, October, 1954, p. 549, 10 pp., 7 tables, 6 ff.)

Note.—Among other articles in this issue of *Irrigation & Power*, we should like to mention: Design of Siphons, by N. S. Gorunda Ras, p. 487, 9 pp., 13 ff.; Harnessing of Wind Power, Some Technical Aspects in Relation to its Future Development in India, by V. Cadambe, p. 528, 10 pp.; Pathri Power Station on the Ganga Grid, by B. S. Mathu, p. 541, 4 pp., 2 ff.